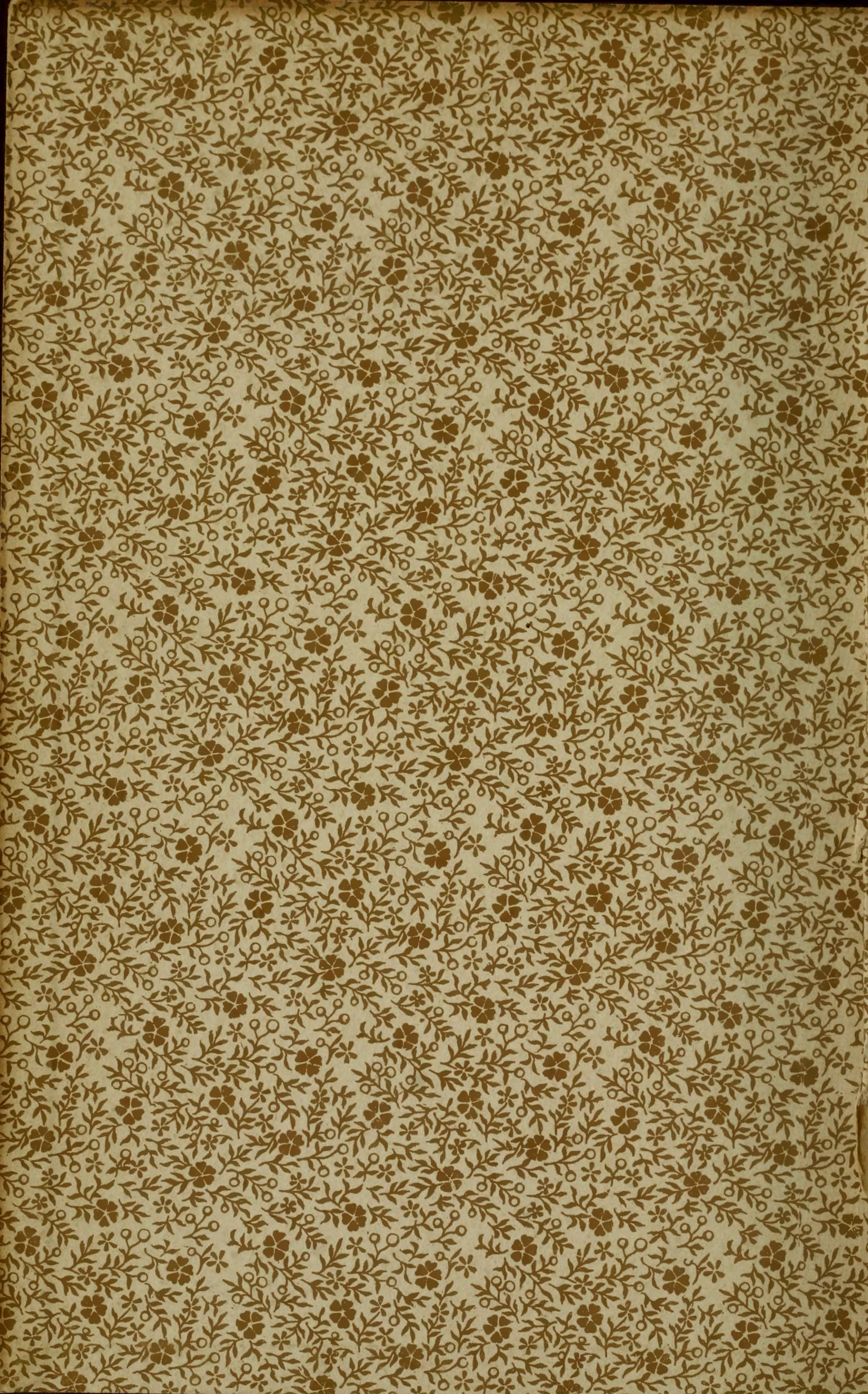

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MANUAL

OF THE

American Railway Engineering Association

Definitions of Terms
Designs and Plans
Specifications for
Material and Workmanship
Principles of Practice

FOR

RAILWAY ENGINEERING

EDITION OF 1929

Endorsed and Approved by Board of Directors,
American Railway Association

Published by

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Manual of the American Railway Engineering Association

FOREWORD

This A.D. 1929 edition of the Manual of the American Railway Engineering Association is the sixth revised edition. It is the statement of the condensed formal conclusions, to and including the 1929 annual convention, of the American Railway Engineering Association, covering principles, definitions, designs, specifications and recommended practice for economic location, construction, maintenance, and basic physical elements of operation of railways.

This Manual is built upon, is validated by, and is the crystallization of 30 years of never-ceasing, recessless work of the Association through the perpetual investigations, studies, reports and recommendations of the Association committees on subjects definitely and annually assigned in the Association's outline of work by the Board of Direction.

The scope and quality of the work of the Association and the broad foundation upon which the Manual is built are revealed in general in the Constitution and in particular in the published Proceedings of the Association, now numbering 30 volumes, containing 30,000 pages of Committee reports and findings and Association conclusions and actions covering 30 years of highly concentrated work, there now being 23 Standing and 4 Special Committees composed of a total of 950 Committee members actively participating in committee-work. In addition, there is the unrecorded but large and invaluable work of the membership at large which collaborates definitely with the Committees individually in the making of their investigations, studies and reports. Individually and collectively, these builders of the Manual are highly-trained and widely experienced in the subject-matters covered by the Manual. The conclusions and recommended practice of the Manual of the American Railway Engineering Association are, therefore, authoritative and dependable cross-sections of the composite judgment of men who build, maintain and operate railways.

Membership in the Association is not limited to North America. It extends to other Continents, and the Manual is accepted as authoritative throughout the railway transportation world.

No reference to the personnel and work of the Association would be comprehensive without recognition of the contribution made by colleges and universities through representatives from their faculties who are members of the Association and rendering distinguished service.

Like acknowledgment is also made to those representatives of government, industry and science who are members of the Association or otherwise collaborate in its work.

The Manual is static only from annual convention to annual convention. At each convention and resulting from the ever-advancing work of the Association, there is some revision of or addition to the Manual, or both revision and addition as recommended by a Committee or Committees and approved by the convention. Currently to reflect the status of the progressive art of transportation, the Manual is necessarily a live and growing thing. Annual changes in it are issued as annual supplements to the Manual until the number of supplements warrants a new edition of the Manual. The 1921 edition, the last previous one, contains 1004 pages. This 1929 edition contains 1534 pages. This indicates the vitality of the Association and the progress of its work.

The Association is conservative in approving anything for inclusion in the Manual. Generally, recommendations of Committees must be supported by more than one year's investigation and study before they are accepted for publication in the Manual. Usually, Committee recommendations rest upon several years' work. Otherwise, they are usually referred back to the Committee for further consideration.

The Manual should be illuminated by study of the Committee reports published in the Bulletins and Proceedings of the Association. These reports are the background and foundation upon which the Manual is built. They are storehouses of information.

The Association was organized in the year 1899 with 300 Charter Members for "The advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways." The membership as of March, 1929, is 2790.

The contents of this Manual have also been endorsed and approved by the Board of Directors of the American Railway Association.

THE AMERICAN RAILWAY
ENGINEERING ASSOCIATION,
By the Board of Direction.

Attest:

E. H. Fritch

Secretary.

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GENERAL RULES FOR THE PUBLICATION OF THE "MANUAL"

Title

1. The title of the volume will be "Manual of the American Railway Engineering Association."

Discretionary Powers of Board of Direction

2. The Board of Direction shall edit the Manual and shall have authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Adoption of Reports Not Binding

3. Matters adopted by the Association and subsequently published in the Manual shall be considered in the direction of good practice, but shall not be binding on the members.

Contents

4. The Manual will only include conclusions relating to definitions, specifications and principles of practice as have been made the subject of a special study by a Standing or Special Committee and embodied in a Committee report, published not less than thirty days prior to the annual convention, and submitted by the Committee to the annual convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the American Railway Association, may be referred to that Association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the Committee report and subsequent discussion and the final action of the Association.

Revision

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent annual convention, provided such changes are proposed in time for publication not less than thirty days prior to the annual convention, and in the following manner: (a) Upon recommendation of the Committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. The Manual will be revised either by publishing a new edition or a supplemental pamphlet as promptly as possible after each annual convention.

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SPECIAL COMMITTEE

[1]CLASSIFICATION OF RAILWAYS

Class "A" includes all districts of a railway having more than one main track, or those districts of a railway having a single main track with a traffic that equals or exceeds the following:

Freight car mileage passing over district per year per mile, 150,000; or, Passenger car mileage per year per mile of district, 10,000; with maximum speed of passenger trains of 50 miles per hour.

Class "B" includes all districts of a railway having a single main track with a traffic that is less than the minimum prescribed for Class "A," and that equals or exceeds the following:

Freight car mileage passing over district per year per mile, 50,000; or Passenger car mileage per year per mile of district, 5,000; with maximum speed of passenger trains of 40 miles per hour.

Class "C" includes all districts of a railway not meeting the traffic requirements of Classes "A" or "B."

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[1] Vol. 7, 1906, pp. 331, 340; adopted by letter-ballot, June, 1906; Vol. 8, 1907, p. 15.

COMMITTEE I

ROADWAY

[1]DEFINITIONS

GENERAL

Borrow (noun).—All material, used in making embankments, which does not come from necessary excavation.

Classification.—Arranging the material in groups according to its character.

Contract.—A written agreement between two or more parties specifying terms, conditions, etc., under which certain obligations must be performed. (Specifications are a part of the contract.)

Estimate (noun).—A statement showing probable cost of a proposed piece of work.

- (a) Progress Estimate.—An estimate made from time to time showing work performed or material furnished as the work progresses.
- (b) Final Estimate.—An estimate made from final checked quantities showing work performed and material furnished upon which final payment is made.

Estimate (verb.)—The act of making an estimate.

Flood Damage.—Any and all damage to railway property caused by any unusual flow of water.

Quantities.—The amount of material to be handled, expressed in the usual units.

Slide.—The movement of a part of the earth under the force of gravity.

Soft Spot.—Small areas in excavation or embankment, or the sub-soil under an embankment, saturated with water and having a relatively small supporting power.

Specification.—That part of the contract describing the materials for or the details of construction.

Stock-Pass.—A culvert or bridge opening under the track, primarily for the passage of stock.

Unit Price.—The price per unit of the various quantities specified in a contract for which a certain work is to be performed.

Washout.—An erosion of the permanent roadbed by storm or flood to such an extent as would cause delay of trains, or endanger traffic.

RIGHT-OF-WAY

Right-of-Way.—The land or water rights necessary for the roadbed and its accessories.

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[1] Adopted, Vol. 7, 1906, pp. 341, 442, 443; Vol. 11, Part 2, 1910, pp. 1063, 1087; Vol. 16, 1915, pp. 566, 1071; Vol. 22, 1921, pp. 697, 1051; Vol. 23, 1922, pp. 394, 1095; Vol. 25, 1924, pp. 358, 1269; Vol. 27, 1926, pp. 761, 1400; Vol. 28, 1927, pp. 841, 1454; Vol. 30, 1929, pp. 213, 1341.

Specifications for Corrugated Metal Culvert Pipe for Railroad Use (Vol. 31, p. 641; Bul. 327, p. 3).

Specifications for Cast Iron Culvert Pipe (Vol. 31, p. 645; Bul. 327, p. 6).

Roadbed.—The finished surface of the roadway upon which the track and ballast rest.

Roadway.—That part of the right-of-way of a railway prepared to receive the track. (During construction the roadway is often referred to as the "grade.")

Station Grounds.—Property to be used for station purposes.

TECHNICAL

Alinement.—The horizontal location of a railway with reference to curves and tangents.

Center Line.—A line adopted to be the center line of the track or tracks.

Construction Station.—A distance of 100 ft. measured along the center line and designated by a stake bearing its number.

Contour.—The line of intersection of a horizontal plane and the surface of the ground.

Cross-Section.—A vertical section of the ground at right angles to the center line.

Center Stakes.—Stakes indicating the center line.

Elevation or Height.—The distance of any given point above or below an established plane or datum.

Finishing Stakes.—Final stakes set for the completion of the work.

Grade (verb).—To prepare the ground for the reception of the ballast and track.

Grade Line.—The line on the profile representing the tops of embankments and the bottoms of cuttings ready to receive the ballast; and is the intersection of the plane of the roadbed with a vertical plane through the center line.

Gradient.—The rate of inclination of the grade-line from the horizontal.

Location.—The center line and grade line of a railway established, preparatory to its future construction.

Plan.—A drawing furnished for guidance of work.

Profile.—The intersection of a vertical plane through the center line with the surface of the ground and the plane of the roadbed, or a drawing representing the same.

Slope.—The inclined face of a cutting or embankment.

Slope Stakes.—Stakes set to indicate the top or bottom of a slope.

Subgrade.—The tops of embankments and bottoms of cuttings ready to receive the ballast.

Top of Slope.—The intersection of a slope with the ground surface in cuts, and the plane of roadbed on embankment.

Toe of Slope.—The intersection of a slope with the ground surface in embankments, and the plane of roadbed in cuts.

CLEARING

Brush.—Trees less than 4-inch stump-top diameter, shrubs or branches of trees that have been cut off.

Clearing.—Removing natural and artificial perishable obstructions to grading.

Grubbing.—Removing the stumps and roots.

DRAINAGE

Bog.—Soft, spongy ground, usually wet and composed of more or less vegetable matter.

Channel.—A depression in which a stream flows.

Culvert.—A covered opening under the roadbed for the passage of water or for other purposes.

Drain.—An artificial waterway for conducting water from the roadway.

Drainage.—The interception and removal of water from, upon or under the roadway.

Ditch.—An open artificial waterway for providing drainage.

Intercepting Ditch.—An open artificial waterway for preventing surface water from flowing over the slopes of a cut or against the foot of an embankment.

Subdrain.—A covered drain, below the roadbed or ground surface, receiving the water along its length by absorption or through the joints.

Tile Drain.—An underground drain constructed of clay or cement pipe.

Trench.—A long relatively narrow excavation the depth of which is greater than its width.

Waterway.—A channel, either natural or artificial, for conducting the flow of water.

GRADING

Average Haul.—The average distance material is to be hauled.

Benched.—Formed into a series of benches.

Berm.—(a) The space left between the top or toe of slope and excavation made for intercepting ditches or borrow pits; (b) An approximately horizontal space introduced in a slope.

Borrow (verb.)—To take material from a borrow pit.

Borrow (noun).—Material removed from a borrow pit.

Borrow Pit.—An excavation made for the purpose of obtaining material.

Casting (verb).—Disposing of excavated material by a single operation either by hand or machinery.

Embankment (or Fill).—A bank of earth, rock or other material constructed above the natural ground surface.

Excavation (or Cutting).—(a) The cutting down of the natural ground surface; (b) The material taken from cuttings, borrow pits or foundation pits; (c) The space formed by removing material.

Foundation Pit.—An excavation made for laying the foundation of a structure.

Grade (noun).—The ratio of rise, or fall, of the grade line to its length.

Note.—The term "Grade" is sometimes used to designate the finished roadbed, but such use conflicts with the meaning of "Grade" as given above and it should not be so used.

HAUL.—The distance material is moved in the construction of the roadway.

FREE HAUL.—The distance within which material is moved without extra compensation.

OVERHAUL.—The number of cubic yards moved through the overhaul distance multiplied by the overhaul distance in units of 100 feet.

OVERHAUL DISTANCE.—The distance beyond the free-haul limit that material is hauled in constructing the roadway, for which extra compensation is allowed.

RAMP.—An inclined approach.

ROADBED SHOULDER.—That portion of the subgrade lying between the ballast covered portion and the ditch in cuts and the top of slope on embankments.

SETTLEMENT (noun).—The term settlement as applied to grading material is the reduction in elevation of an embankment caused by shrinkage or subsidence.

SHRINKAGE (noun).—The term shrinkage as applied to grading material is the difference in volume between the material excavated and the ultimate volume of the same material in the embankment after it has reached a state of equilibrium, when the latter is the smaller.

STATION MEN (noun).—Men engaged in station work.

STATION WORK (noun).—A small piece of grading work extending over one or more stations.

STEPPED.—Formed with a series of steps.

SUBGRADE (noun).—The finished surface of the roadbed before the application of ballast or track.

SUBSIDENCE (noun).—That portion of an embankment which has settled below the original surface of the ground.

SWELL.—The term swell as applied to grading material is the difference in volume between the material excavated and the ultimate volume of the same material in the embankment after it has reached a state of equilibrium, when the latter is the greater.

TAMPED (or Packed).—Packed down by light blows.

WASTE.—Material from excavation not used in the formation of the roadway.

WASTE OR SPOIL BANKS.—Banks outside the roadway formed by waste.

TUNNELS

CURB.—A broad, flat ring of wood, iron or masonry, placed under the bottom of a shaft to prevent unequal settlement, or built into the walls at intervals for the same purpose.

ROCK.—A solid mass of mineral substance.

SHAFT.—A pit or well sunk from the ground surface above into a tunnel for the purpose of furnishing ventilation or for facilitating the work by increasing the number of points from which it may be carried on.

TUNNEL.—An excavated passageway under ground or water.

WELL (or Sump).—A cistern or well into which water may be conducted by ditches to drain other portions of a piece of work.

[2]GENERAL CONTRACT REQUIREMENTS

(1) Similarity in the form of specifications.

(2) Measurement of clearing and grubbing should be made in units of one hundred (100) feet square.

(3) A threefold classification of materials: "Solid Rock," "Loose Rock" and "Common Excavation," and in special cases such additional classification of material as may seem necessary, such additional classes to be distinctly defined and specified in the contract.

(4) Profiles should be made complete in regard to distribution of material.

(5) The distance between center lines of main tracks on tangents should be not less than 13 feet; on curves this distance should be increased enough to maintain an equivalent clearance between equipment on adjoining tracks.

(6) Rock excavations should be taken out not less than six (6) inches inches below subgrade.

(7) No waste should be permitted above subgrade closer than ten (10) feet from the slope stakes.

(8) Information on profiles should be so given and arranged that units and costs of grading can be intelligently estimated.

[3]WIDTH OF ROADWAY AT SUBGRADE

(1) Single track, Class A railways, with constant and heavy traffic, should have a minimum permanent width of twenty (20) feet at subgrade. A roadbed shoulder of not less than eighteen (18) inches should be maintained outside of the toe of the ballast slope.

(2) In the theory upon which the width of embankment at subgrade is based it is considered that the track, in excavations, is placed upon what is virtually a low embankment; and in order to preserve uniformity of conditions immediately under the track throughout the line, the width of subgrade in excavations should be made the same as on embankments, outside of which sufficient room should be allowed for side ditches.

[4]SLOPES OF ROADWAY CROSS-SECTION

Local conditions and the character of the material should always be taken into account in determining the construction slopes of the roadway cross-section.

In cuts the slopes should be as steep as the material will stand permanently, while on embankments, because of operating and maintenance conditions, the slopes should not be steeper than one and one-half to one unless the embankment is made very wide.

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[2] Adopted, Vol. 4, 1903, pp. 32, 35, 39, 44, 66, 74; Vol. 5, 1904, pp. 688, 719; Vol. 6, 1905, pp. 123, 136, 142, 144, 145, 164-173; Vol. 16, 1915, pp. 567, 1075; Vol. 27, 1926, pp. 761, 1400.

[3] Adopted, Vol. 3, 1902, pp. 34, 37, 43; Vol. 6, 1905, pp. 122, 123; Vol. 25, 1924, pp. 380, 1269; Vol. 28, 1927, pp. 841, 1454.

[4] Adopted, Vol. 3, 1902, pp. 34, 45; Vol. 6, 1905, pp. 122, 123; Vol. 27, 1926, pp. 761, 1403.

[5]SPECIFICATIONS FOR THE FORMATION OF THE ROADWAY

GENERAL

Alinement

1. The center of the roadway shall conform in alinement to the center stakes.

Subgrade

2. The grade-line on the profile denotes subgrade, and this term indicates the tops of embankments or the bottoms of excavations ready to receive the ballast.

Cross-Section

3. The roadway shall be formed to the section, slopes and dimensions shown upon the standard drawings, or as may be directed from time to time.

Width of Roadway

4. When finished and properly settled the roadway shall conform to the finishing stakes and shall be of the following dimensions at subgrade, for single track, viz.:

On embankments.......................................(......) feet wide, and in excavation.......................................(......) feet, exclusive of the width necessary for ditches. For each additional track an additional width of.......................................(......) feet shall be made.

Slopes

5. The slopes of embankments and excavations shall be of the following inclinations, as expressed in the ratio of the horizontal distance to the vertical rise:

Embankments: Not steeper than one and one-half to one.
Excavations: ~~Ordinary Earth~~—One and one-half to one;
Loose Rock—One-half to one;
Solid Rock—One-quarter to one.

These slopes may be varied according to circumstances, and the slopes shall be made as directed in each particular case.

CLEARING

Extent of Clearing

6. The right-of-way and station grounds, except any portions thereof that may be reserved, shall be cleared of all trees, brush and perishable materials of whatsoever nature.

Disposal of Brush, etc.

7. All these materials, except as hereinafter mentioned, shall be burned or otherwise removed, as may be directed, and without injury to adjoining property.

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[5] Adopted, Vol. 4, 1903, pp. 20-29, 33-35; 78-109; Vol. 5, 1904, pp. 675-684, 688, 719; Vol. 6, 1905, pp. 125-136, 143-164; Vol. 11, Part 2, 1910, pp. 1062, 1063; Vol. 16, 1915, pp. 567, 1075; Vol. 26, 1925, pp. 420, 1278; Vol. 27, 1926, pp. 761, 1403.

Stumps

8. Where clearing is to be done, stumps shall be cut close to the ground, not higher than the stump-top diameter for trees twelve (12) inches and less in diameter, and not higher than eighteen (18) inches for trees whose stump-top diameter exceeds twelve (12) inches, except between slope stakes of embankments, where stumps shall be cut so that the depth of filling over them shall not be less than two and one-half (2½) feet.

Clearing in Advance

9. The work of clearing shall be kept at least one thousand (1000) feet in advance of grading.

Cutting and Piling Wood

10. All trees which may be reserved shall be stripped of their tops and branches, made into ties, or cut to such lengths as may be directed, and neatly piled at such places on the right-of-way as may be designated, for which service payment shall be made by the tie, or by the cord of one hundred and twenty-eight (128) cubic feet, or by the thousand feet B.M., top scale measure as may be specified.

Isolated Trees, Buildings, etc.

11. Where isolated trees, or where buildings exist, payment shall be made for the removal thereof at a price to be agreed upon before removal.

Measurement

12. Measurement of clearing and payment for the same shall be by units of one hundred (100) feet square, or fraction thereof, actually cleared.

GRUBBING

Extent

13. Stumps shall be grubbed entirely from all places where excavations occur, including ground from which material is to be borrowed as well as from ditches, new channels for waterways and other places where required.

Grubbing shall also be required between the slope stakes of all embankments of less than two and one-half (2½) feet in height.

Grubbing in Advance

14. The work of grubbing shall be kept at least three hundred (300) feet in advance of grading.

Measurement

15. Measurement of grubbing shall be estimated upon all excavation actually done, and the space to be covered by all embankments of less than two and one-half (2½) feet in height. Payment for the same shall be by units of one hundred (100) feet square, or fraction thereof, actually grubbed.

GRADING

16. The term "Grading" in these specifications includes all excavations and embankments for the formation of the roadbed, ditching, diversions of roads and streams, and all similar works pertaining to the construction of the railway, its sidetracks and station grounds.

Work Included—Classification

17. All material excavated shall be classified as "Solid Rock," "Loose Rock," "Common Excavation," and such additional classifications of material as may be established before the award of the contract.

Solid Rock

18. "Solid Rock" classification shall comprise rock in solid beds or masses of boulders, measuring one cubic yard or more, and all other material which can most economically be removed by blasting.

Loose Rock

19. "Loose Rock" classification shall comprise all detached masses of rock or stone of more than one cubic foot and less than one cubic yard, and all other rock which can be properly removed by pick and bar and without blasting; although steam shovel or blasting may be resorted to on favorable occasions in order to facilitate the work.

Common Excavation

20. "Common Excavation" classification shall comprise all materials that do not come under the classification of "Solid Rock," "Loose Rock," or such other classification as may be established.

Finishing Slopes

21. Slopes of all excavations shall be cut true and straight, and all loose stones in the slopes shall be removed.

Excavation Below Subgrade

22. Rock excavation shall be taken out .... (......) inches below subgrade and be refilled to subgrade with approved sub-ballast or ballast material. The measurement of excavation shall be made to the bottom of the material removed.

Excess Excavation and Slips

23. The classification of the material excavated shall be in accordance with its condition at the time of its removal, regardless of prior conditions. The measurement of the material shall be the original space occupied, regardless of the classification. Excavation in excess of the authorized cross-section shall not be included in the measurement except in removal of unpreventable slides.

Disposal of Excess Excavation

24. Where the quantity of excavation exceeds that required to make the embankments to standard cross-section, the surplus shall be used to widen the embankments uniformly along one or both sides, as may be directed, and no material shall be deposited in waste banks unless such waste be indicated either on the profiles or by written order.

Waste Banks

25. Where wasting is ordered the material shall, if possible, be deposited below grade-line, and under no circumstances shall the waste bank have its nearest edge within .... (......) feet of the slope stakes of the cutting.

Borrow

26. Where the quantity of excavation from the cuttings of standard cross-section is insufficient to form the embankments, the deficiency shall be made up by widening the cuttings on one or both sides of the center line, as may be directed. No material shall be taken from borrow pits unless such borrow be indicated either on the profiles or by written order.

When steam shovels are used borrow pits should, if possible, be so located that the bottom of the pit will not be below subgrade, or prospective subgrade. Where it is necessary to borrow from below subgrade the borrow pit should be made far enough away from the roadbed so that it will not require refilling at some future time, also so that water which may stand in the pit will not affect the roadbed.

Approximate Quantities Shown

27. The classification and quantities shown on the profile exhibited for distribution of material are approximate only, and shall in no way govern the final estimate. The Company reserves the right to increase or diminish the quantities given without affecting the contract unit prices for the various parts of the work.

Reserving Gravel

28. Gravel, stone or any other material suitable for special use of the Company, which is found within the excavations, shall, when required, be reserved and deposited in convenient places on the right-of-way, as directed. Other suitable material in the vicinity shall be substituted, as required, to complete the embankments.

Berm in Rock Cuttings

29. A berm of .... (......) feet shall be left between the top of slope of rock cuttings and toe of slope of the overlying earth.

Intercepting Ditches

30. Intercepting ditches, when ordered, shall be made at the top of the slopes of all cuttings where the ground falls toward the top of the slopes. These ditches must diverge sufficiently to prevent erosion of the adjoining embankment. The cross-sections and locations of such ditches shall be designated. If required, they shall be excavated in advance of opening the cutting.

Ditches in Cuttings

31. Ditches shall be formed at the bottoms of the slopes in cuttings, according to cross-sections shown upon the plans, or such modifications thereof as may be directed. They shall be neatly made, clear of obstruction, and at the lower ends must diverge sufficiently to prevent erosion of the adjoining embankments.

Subdrains

32. Subdrains of tile shall be constructed of the size and location as directed, and to the depth and grade established for them. The tile bed shall be cut true in line and where practical with half-round bottom. Where impractical to provide the half-round bottom, planks or strips of wood must be so set or other provision made to hold the tile in true line and grade.

The tile trench must be filled with cinders or other suitable porous material, to a depth of twenty-four inches above the top of the tile, and the remainder of the trench filled with any material which is sufficiently porous to permit of good drainage. Pure clay should not be used for refilling any part of a drainage ditch.

Unsuitable Material

33. Excavations incident to the construction of the roadbed, ditches, channels and roadways shall be used in forming the embankments. Frozen or other unsuitable material shall not be permitted to enter into their composition.

Formation in Layers

34. When directed, embankments shall be built in horizontal layers of .... (......) feet in thickness. These layers must be of the full width of the embankment and built to the true slope, and not widened with loose material from the top. The most suitable material shall be reserved for finishing the surface; large stones shall not be permitted within a depth of at least .... (......) feet below subgrade.

Shrinkage

35. Embankments shall be carried to such height above subgrade and to such increased width as may be deemed a necessary provision for shrinkage, compression and washing. As the embankments become consolidated, their sides shall be carefully trimmed to the proper slopes, and they must be maintained to their proper height, dimensions and shape until the work is finally accepted.

Embankments on Slopes

36. Where an embankment is to be placed on sloping ground, the surface shall be deeply plowed or stepped. Whenever directed, boggy or unsuitable material shall be excavated so that the embankment shall be on a firm foundation.

Embankments Across Swamps

37. In crossing bogs or swamps of unsound bottom for light fills, a special substructure of logs and brushwood may be required. The logs forming this foundation to be not less than six (6) inches in diameter at the small ends. If necessary, there shall be two or more layers crossing each other at right angles. The logs of each layer shall be placed close together, with broken joints, and covered closely with brush. The bottom layer shall be placed transversely to the roadway, and shall project at least five (5) feet beyond the slope stakes of the embankment.

Measurements and payment for this substructure shall be by units of one hundred (100) feet square, or decimal thereof, of area covered by each layer.

Filling Trestles

38. In forming embankments from trestles, the material shall be thoroughly compacted between the trestle bents and around and under all parts of the structure. In case of train filling by means of a temporary trestle, the material shall be uniformly spread in the fill.

Embankments at Trestles

39. Embankments abutting the ends of trestle bridges shall be brought forward upon the structure a distance of at least .... (......) feet, with increased width of .... (......) feet in order to form a full roadbed.

Finishing Subgrade

40. The subgrade shall be compact and finished to a true sloped or crowned surface as called for by the plans, and must leave no depression or irregularity which will hold water or prevent proper drainage.

Embankments over Masonry, etc.

41. Material for embankments over or about masonry or other structures shall be deposited in thin layers, and each layer carefully tamped. Special care must be exercised that no excessive strain be placed upon these structures. Only the best material shall be permitted for the purpose of such filling. The contract price for excavation shall cover the cost of obtaining, distributing and packing the material behind, over and around all such structures.

BORROW PITS

Land Provided

42. Land for borrow pits or waste banks shall be provided by the Railway Company.

Drainage

43. Borrow pits shall be connected with ditches and drained to the nearest water course, when required. Unless directed, material shall not be borrowed to a depth that will prevent proper drainage.

Slopes and Berms

44. Side slopes of borrow pits on the right-of-way shall be the same as used in the cross-section of the adjoining roadway. A berm of not less than .... (......) feet in width shall be left between slope stakes of the embankment and the edge of the borrow pit. A berm of not less than .... (......) feet shall be left between the outside slope of the borrow pit and the right-of-way line. Berms shall consist of the original unbroken ground.

Cross-Sectioning of Pits

45. Borrow pits shall not be excavated before they have been staked out. Borrowing must be done in regular shape in order to admit of ready and accurate measurement. Borrowing or wasting of material will not be permitted on land set apart for station grounds or for other special purposes, except by written directions.

MEASUREMENT OF GRADING

Measurement

46. Measurement of grading shall be by the cubic yard, and in accordance with the proper classifications. Measurements shall be made in excavation only, except where otherwise specifically directed.

Completion of Work

47. The completed work shall include the excavation of the material by whatever method is adopted, the loading, transportation and deposit of the same in the place or places designated, and in the manner prescribed, the plowing or benching of slopes and the finishing of the roadbed, slopes and ditches, and all other work which may be incident to the completion of the grading.

Embankment Measurement

48. If it be impracticable to measure borrowed material in excavation, it may be measured in embankment, using the cross-section notes of the embankment, and making a just and reasonable allowance for change in bulk, so that the quantities shall equal the excavation quantities as nearly as possible.

Borrow Classification

49. No classification or allowance shall be made for loose or solid rock in borrow pits unless specific written instructions are given to the contrary, it being the intent and meaning of these specifications that all borrowed material shall be classified and paid for as common excavation.

TUNNEL EXCAVATION

Line, Grade and Cross-Section

50. Tunnels shall be excavated to the alinement, gradients and sections shown upon the plans, or to such modifications thereof as may be directed.

Bottom and Rock Tunnels

51. The material from rock tunnels shall be taken out .... (......) inches below subgrade and refilled to subgrade with approved material.

Blasting

52. Blasting shall be done with care to avoid damage to the roof or sides. All insecure pieces of rock beyond the authorized cross-section must be removed at once, but shall not be included in the excavation measurement.

Excess Excavation

53. Excavation in excess of the authorized cross-section shall not be paid for.

Price to Include

54. The price paid for tunnel excavation shall embrace the cost of removal of all materials between the outer faces of the portals. It shall include the loosening, loading, transportation and placing of the materials in embankment or waste banks, as directed. It shall also include whatever materials and labor are required for temporary props, supports and scaffolding for the safe prosecution of the work, as well as all expense of keeping the tunnel ventilated and free from water, oil or gas.

Niches or Recesses

55. Niches or recesses for the protection and convenience of the railway employees shall be provided at designated intervals.

Shafts

56. The location, number and dimensions of all shafts shall be determined. The excavation price for them shall cover all materials contained within the specified cross-section between the surface of the ground and the connection of the shafts with the tunnel. This price shall also cover all material and labor for curbing and support of the sides of the shafts as may be required, the cost of keeping the shafts ventilated and free from water, oil or gas, as well as the cost of all pumping and hoisting machinery.

Wells or Sumps

57. Wells or sumps within the tunnel necessary for its permanent drainage shall be made as directed and paid for at the same rate per cubic yard as for tunnel excavation.

Haul

58. The contract price per cubic yard for tunnel and shaft excavation, respectively, cover any haul found necessary in placing the material where designated within limits agreed upon. There shall be no allowance for any so-termed overhaul.

CLAUSES SPECIALLY APPLICABLE TO REVISION OF EXISTING LINE OR WIDENING FOR ADDITIONAL TRACK

Safety of and Delay to Train Service

59. The work shall be so arranged that there will be no delay or interference in any manner with the operation of trains.

Whenever the work is liable to affect the movement or safety of trains, the method for doing such work must be submitted for approval, without which it must not be commenced or prosecuted.

Precautions for Safety of Trains and Tracks

60. Heavy blasting close to the operated tracks shall not be done until the proper precautions have been taken and arrangements made to protect all trains and other property and to quickly clear all débris from the track.

Plowing Slopes

61. Wherever the existing embankment of .... (......) feet in height or over is raised or widened, the slope of the existing embankment shall be deeply plowed in order to bind the new material thoroughly to it.

Crossings

62. When a crossing is necessary to transport material across the track, or tracks, the location and construction of the crossing must be approved.

Watchmen, Operators and Flagmen

63. Watchmen shall be provided when and where it is considered necessary for the safety of trains and other property.

Safety Signals

64. All signals necessary to insure the safety of trains shall be placed, maintained and operated by the proper department of the Company. All instructions regarding their observance must be strictly obeyed.

GENERAL CONDITIONS

Temporary Fences

65. Previous to or during the work of grading, suitable temporary fences shall be erected and maintained, if necessary, in order to prevent trespass upon the railway or damage to adjoining property.

Crossings; Damage to Property

66. Suitable roads for public and private use shall be provided and maintained as may be necessary within the limits of the work. All other necessary facilities shall be provided.

Snow and Ice

67. Snow and ice shall be removed when necessary before placing grading material.

Temporary Roads, Trestles, etc.

68. Such temporary roads, bridges, or trestles as may be necessary to facilitate the work shall be provided.

[6]SHRINKAGE AND SUBSIDENCE

General

(1) In determining the allowance for shrinkage to be made in a fill, it should be remembered primarily that it is easier to add to the height of a fill that settles than to lower the track if the settlement does not amount to as much as that anticipated in the original allowance. Therefore, unless the shrinkage of a material is well known in the conditions under which the fill is made, it is best to be well on the safe side; i. e., little or no allowance should be made in height; the extra material, when possible, being deposited where it will be conveniently available for raising the track, as required. The allowance in width should be from about 5 per cent to 20 per cent of the height of the fill, depending on the material and conditions.

(2) The material used for fill varies in shrinkage from sound, non-disintegrating rock, or gravel, which is least, to certain swelling clays, which give the greatest shrinkage both in compactibility and erosion at the slopes. While vegetable loam has a large percentage of actual shrinkage, it so quickly produces a protection cover of vegetation that the shrinkage due to erosion is usually small. Where frozen material must be used in making a fill, heavy settlement must be expected, and this is to be avoided where possible.

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[6] Adopted, Vol. 8, 1907, pp. 307, 308, 349, 350; Vol. 22, 1921, pp. 706, 1051.

(3) The material and contour of the ground supporting the fill is also a matter of considerable importance. This is especially so where unstable material is encountered.

(4) The method of making the fill should also be carefully considered. When the tracks are being raised under traffic, the vertical shrinkage will be largely taken care of in the course of the work. When the fill is made by teams or such means as to reasonably tamp and compact the fill in thin layers, as it is made, the same is true. Where, however, the fill is made by trestle and without puddling or other method of compacting, the settlement is apt to be considerable.

ALLOWANCE FOR SHRINKAGE AND SUBSIDENCE IN ESTIMATING

Shrinkage

(1) Figure a shrinkage of 10 per cent of quantities measured in excavation on earth removed from excavation to embankment.

(2) Ascertain local conditions and results and use them as a guide in estimating swell of rock, considering nature of formation and method of handling.

Subsidence

(3) Some subsidence occurs under all embankments built on any ground except rock. It is very light in sand and gravel. The percentage of subsidence is in general greater under small fills than under large ones.

(4) Subsidence is due to compression or displacement of the strata of earth under the embankment.

(5) Subsidence must always be anticipated in swamps, marshes and bogs, and any land on which there is standing water.

(6) Serious subsidence is local and it is impossible to fix any rule as a guide in estimating or anticipating same.

[7]GRADE REDUCTION WORK

(1) Organization.—The simplest organization is preferable. One man should be in responsible charge of the work, with a staff of Engineers and Supervisors to cover the work; the latter should have control of the men, material and means necessary for their respective sections.

(2) The lowest gradient and lightest curvature which physical conditions and the present and prospective business of the railway will warrant should be established.

(3) The location should be completed before entering on the work of construction.

(4) Surface and waterway drainage should be given first consideration, and, lastly, the roadway drainage in excavation.

(5) The grades of railways and highways should be separated wherever practicable.

(6) Temporary bridges should be eliminated by the substitution of permanent structures.

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[7] Adopted, Vol. 9, 1908, pp. 608, 609, 642-648; Vol. 16, 1915, pp. 572, 1081.

(7) Light, short haul and preparatory work should be done with teams or other light working plant.

(8) Separate tracks for work and traffic should be provided where conditions warrant.

(9) There should be a well-defined plan for conducting heavy excavation before starting work.

[8]TRACK ELEVATION WORK

(1) ORGANIZATION.—A Superintendent of Construction should be in complete charge of the work. The following officers in charge of the various branches of the work should report to him: The Engineers having charge of the contract work and giving lines and grades; the Roadmaster in charge of earth work and track work; the Engineer in charge of masonry and bridges; the Yardmaster in charge of engines and switching. An Assistant Trainmaster, with a Dispatcher, in charge of the operation of traffic over the territory covered by the work in hand, may sometimes be required. If the proportions of the work permit, every person connected with the organization should be relieved from all other duties relating to the operation of the railway.

(2) The railway company should handle with its own forces all work which may interfere with the movement of trains.

(3) As far as practicable, all earth work should be handled by machinery.

(4) The best material for use in filling is that which combines low first cost, ease of handling and stability.

(5) Bridgework, during progress of the work, both railway and highway, should ordinarily consist of temporary bridges, to be replaced by permanent bridges after tracks are elevated or depressed.

(6) Water, sewer and gas pipes, electrical conduits and wires should be cared for and moved by the companies owning them, whether or not the expense is borne by the railway company.

[9]WATERWAYS

The following notes indicate in a general way the information required on survey for waterways:

1. Contour bed of stream.
2. Character bed of stream, mud, sand, gravel, clay, etc.
3. Borings, locate and give character of material found.
4. Direction of current.
5. Character of current—slow, rapid, miles per hour. Does flow change suddenly?
6. Elevation.
    (a) High water mark;
    (b) Average stage of water;
    (c) Low water mark.
7. Drainage area.
8. Profile of line, 500 feet minimum each way.

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[8] Adopted, Vol. 9, 1908, pp. 591, 631-642; Vol. 16, 1915, pp. 572, 1081.

[9] Adopted, Vol. 10, Part 2, 1909, pp. 920, 921, 967-1022, 1097-1099; Vol. 16, 1915, pp. 572, 1081; Vol. 21, 1920, pp. 818, 1427.

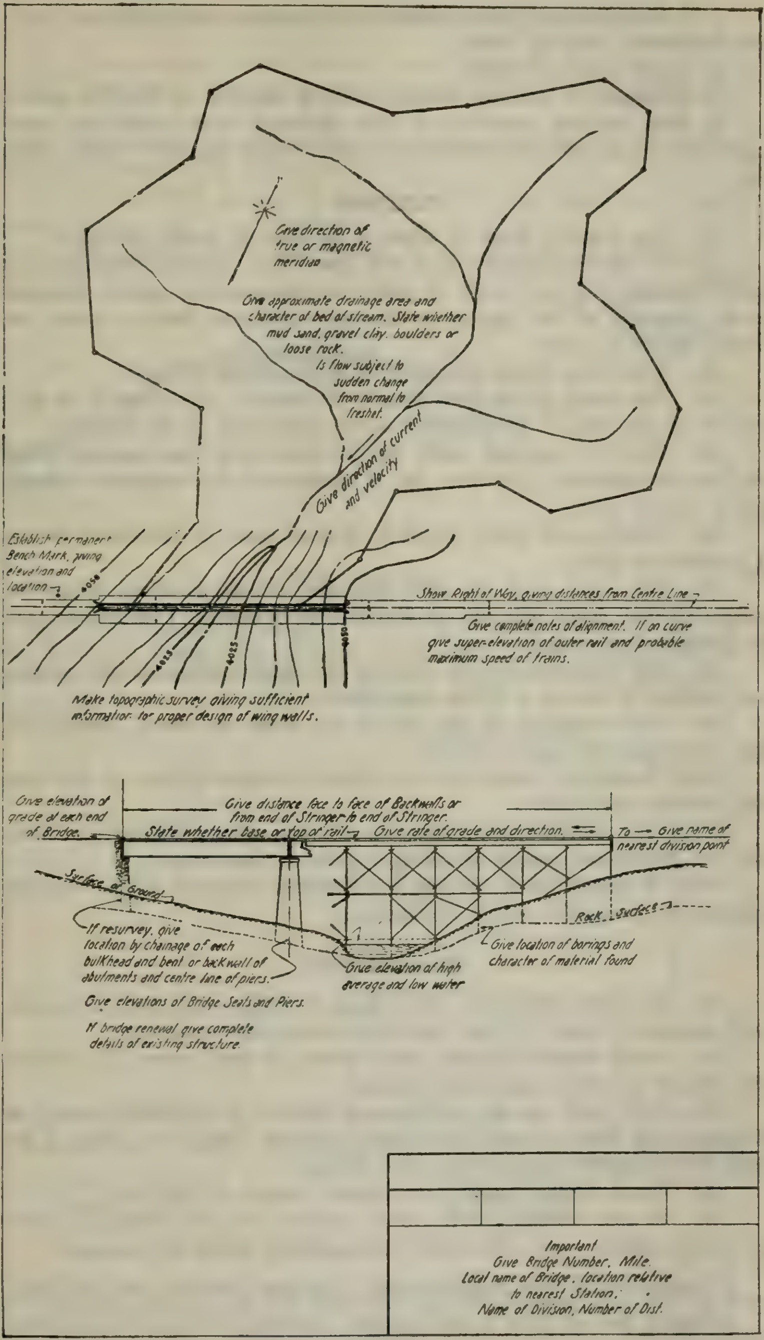
Give direction of true or magnetic meridian
Give approximate drainage area and character of bed of stream. State whether mud sand, gravel clay, boulders or loose rock.
Is flow subject to sudden change from normal to freshet.
Give direction of current and velocity
Establish permanent Bench Mark, giving elevation and location
4050
4025
4025
4050
Show Right of Way, giving distances from Centre Line
Give complete notes of alignment. If on curve give super-elevation of outer rail and probable maximum speed of trains.
Make topographic survey giving sufficient information for proper design of wing walls.
Give elevation of grade at each end of Bridge.
Give distance face to face of Backwalls or from end of Stringer to end of Stringer.
State whether base or top of rail
Give rate of grade and direction.
To → Give name of nearest division point
Surface of Ground
Rock Surface
If resurvey, give location by chainage of each bulkhead and bent or backwall of abutments and centre line of piers.
Give elevation of high average and low water
Give location of borings and character of material found
Give elevations of Bridge Seats and Piers.
If bridge renewal give complete details of existing structure.
Important
Give Bridge Number, Mile.
Local name of Bridge, location relative to nearest Station,
Name of Division, Number of Dist.

FIG. 1

9. If on curve, give full information of curve, superelevation and probable maximum speed of trains.

10. North point and scale.

11. Directions to railway stations, ends of districts or junction points.

12. Plan showing right-of-way with distances from center line, contour lines for a sufficient distance to enable proper design of wing walls, etc.

[10]SLIDES

(1) The primary cause of slides is the lack of proper drainage.

(2) In the construction of a new line when conditions indicative of future trouble with soft spots or slides are encountered, special attention to the diversion of the springs or streams which are likely to cause the trouble should be given.

(3) Each slide should be considered as a problem by itself.

(4) The cause of the slide should be sought. The removal or prevention of the cause is as important as the restoration of the roadway.

(5) Piles or retaining walls for the prevention and cure of slides are not recommended; but their use is permissible for temporary repairs and in special cases.

(6) Underground water should be drained away or intercepted before it reaches the slide.

(7) The surface of the slide and the restored roadway should be graded so that water will run off and not lie in pools. The surface may be compacted or sodded.

(8) The flattening of the slope is the most economical and permanent method of curing a sliding embankment.

(9) The weighting of the toe of the slope to restore equilibrium may sometimes be found efficient.

(10) Facing the slopes with a coating of engine cinders or fine slag will prevent small slides.

(11) The removal of the material is nearly always the most economical and permanent method of curing a slide in excavation.

(12) A relocation of the line is sometimes necessary where the slide assumes the proportion of an avalanche.

[11]WASHOUTS

(1) The ends of trestles and bridges should be efficiently protected. with masonry, riprap, or other protective work when necessary.

(2) Track should be raised above height of flood waters, if possible, and carried on strong and stable roadbed.

(3) The track on an embankment subject to overflow should be ballasted with heavy angular ballast and anchored. The lower slope of the embankment should be protected with riprap.

(4) Track bridges subject to overflow should be anchored.

(5) If the velocity of the water carries away the riprap or other protection against scour, the width of the opening should be increased.

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[10] Adopted, Vol. 10, Part 2, 1909, pp. 921, 1023-1093, 1099-1104; Vol. 11, Part 2, 1910, pp. 1064, 1087; Vol. 16, 1915, pp. 572, 1081; Vol. 23, 1922, pp. 403, 1097.

[11] Adopted, Vol. 10, Part 2, 1909, pp. 921, 1023-1093, 1099-1104; Vol. 16, 1915, pp. 572, 1081.

[12]SURFACE AND SUB-SURFACE DRAINAGE

(1) Water should be kept off the roadbed if possible.

(2) Intercepting ditches should be constructed for the protection of cuts.

(3) Intercepting ditches or pipe drains should be provided for the protection of banks built on saturated soils.

(4) Side ditches should be constructed in cuts through all classes of materials.

(5) Pipe drains should be provided for the drainage of wet cuts.

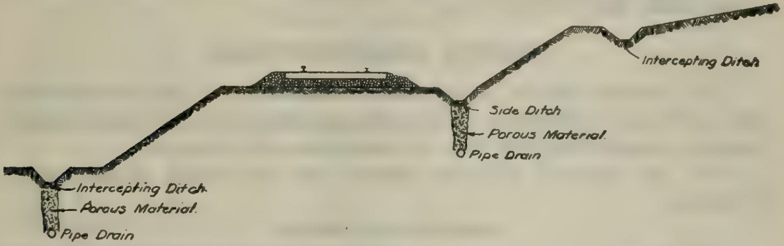
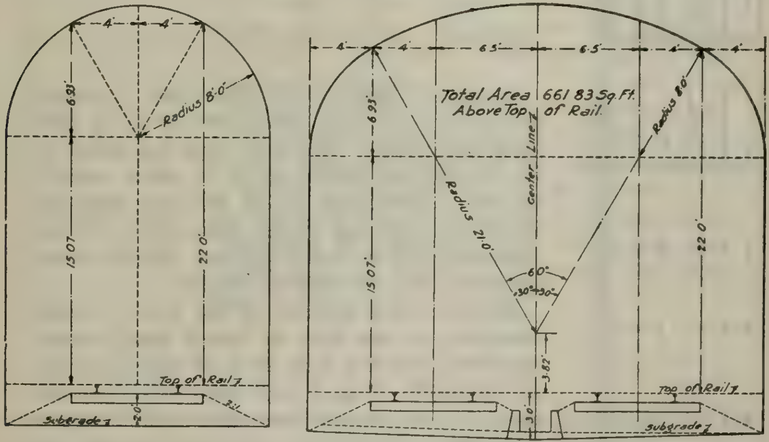


FIG. 2.

[13]TUNNELS

(1) The forms and dimensions of the clear space to be provided for single and for double-track tunnels on tangent should conform to the following diagrams (the height of rail in all cases to be assumed as 6 inches):



SECTION OF TUNNEL.
Single Track.
Tangent.

SECTION OF TUNNEL
Double Track.
Tangent.

FIG. 3.

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[12] Adopted, Vol. 10, Part 2, 1909, pp. 921, 922, 1094-1096, 1104-1106; Vol. 16, 1915, pp. 573, 1081.

[13] Adopted, Vol. 11, Part 2, 1910, pp. 1065-1097; Vol. 12, Part 3, 1911; Vol. 16, 1915, pp. 573, 1081; Vol. 27, 1926, pp. 784, 1403.

(2) The dimensions of the section of tunnels on curved track should be increased and the track placed off the center of tunnel sufficiently to give substantially the clearance given above.

(3) Drainage for a double-track tunnel should occupy a concrete channel midway between the tracks.

(4) Concrete should be used for the permanent tunnel lining, except where local conditions will injure the concrete before it sets.

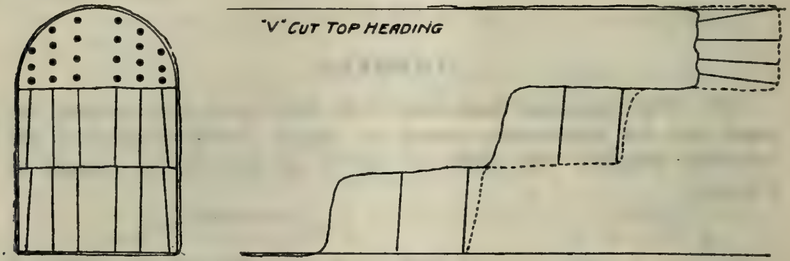
(5) The arch of every brick-lined tunnel should be laid with vitrified brick in rich Portland cement mortar for a width of five feet on each side of the center line of each track.

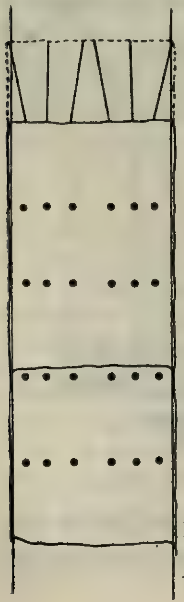
[14]TUNNEL CONSTRUCTION

(1) Railway tunnels, as ordinarily constructed, are more economically built by driving the heading entirely through, first, but such method usually requires a greater length of time for completion of the tunnel.

(2) For material requiring support, the top heading should usually be driven.

SINGLE-TRACK SECTION.





Heading in material of this kind is usually driven by a "V" cut, using from 16 to 22 holes about 8 feet deep. The holes near the middle of the heading are drilled so as to nearly meet at the end. These holes are the first row shot, then the second row and outside holes last. The arrangement of these holes will vary slightly according to the way the material breaks.

Bench in hard material of this kind is usually taken out in two lifts of almost equal weight. Sub-bench is drilled from 20 to 40 feet in advance of the bench. From 4 to 8 holes in a row, with about 6 to 8-foot face, are used in both sub-bench and bench. One or two rows of holes may be used. Center holes are shot first, round and side holes last.

Fig. 4—Method of Tunnel Construction in Hard Rock with Few Seams

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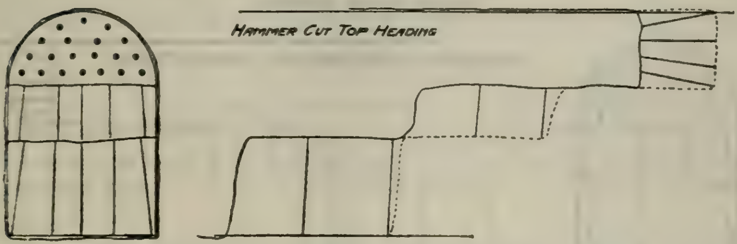
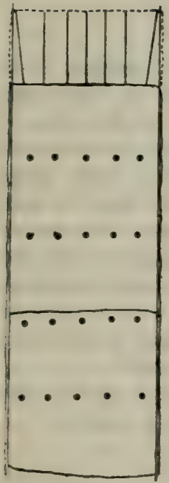
[14] Adopted, Vol. 15, 1914, pp. 392, 1031.

(3) It is economical and expedient to use an electric shovel or an air-shovel for the removal of the bench, where the section of the tunnel permits the safe operation of the same; and where the material does not require support there are advantages in low cost and quick removal of the bench in driving the heading at the subgrade line.

SINGLE-TRACK SECTION.





Heading in material of this kind is usually driven by a "hammer cut," using from 14 to 20 holes 6 to 10 feet deep. The bottom row of holes is inclined at about an angle of 30 degrees. The bottom row is shot first and each row shown in succession. These holes should be arranged to suit the seams in the material.

Bench in material of this kind is usually taken out in two lifts, but the sub-bench is not as deep as the bench. Sub-bench is best drilled from 20 to 40 feet in advance of the bench. From 4 to 6 holes in a row may be used with 6 to 10-foot face. The bench is sometimes taken out in one lift. Center holes are shot first, round and side holes last.

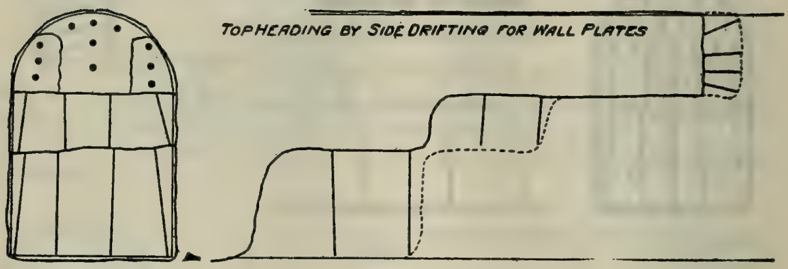
Fig. 5—Method of Tunnel Construction in Moderately Hard Rock with Seams

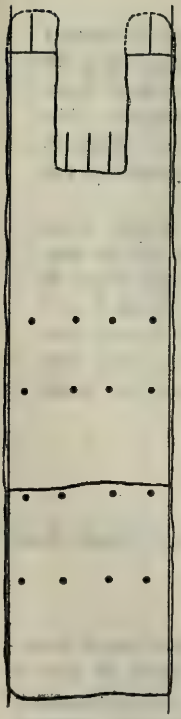
(4) Where the time limit is of value, the heading and bench should be excavated at the same time, the heading being kept about 50 feet in advance of the bench. Where the material of the roof is not self-supporting and timbering is to be resorted to, the bench should not be removed until the wall-plates are laid and the arch ribs (or centering) safely put up.

(5) Opposing grades should preferably not meet between the portals of a tunnel, so as to put a summit in the tunnel, and where practicable, the alinement and ascending grades in the tunnel should be in the same direction as the prevailing winds.

(6) Figs. 4, 5 and 6 are representative of American practice in single-track tunnel construction, where the time limit is of value.

SINGLE-TRACK SECTION.





This method is only used when material is so soft that heading cannot be driven for full length of timber used for wall plate. Drifts about 4 feet wide and 6 feet high are driven for each wall plate, and then core is taken out as timber rings are put in. Three or four holes may be used from 3 to 5 feet deep in each drift. The amount of shooting necessary depends entirely upon the softness of the material. It can often be picked. The core may be soft enough to pick, or may be shot with from 4 to 8 holes, either drilled from face as shown or from sides of drifts.

Bench in this class of material is shot in one or two lifts. Very few holes are necessary.

Fig. 6—Method of Tunnel Construction in Soft Rock or Hard Clay

[15]TUNNEL VENTILATION

(1) The most practicable, effective and economical artificial ventilation for tunnels carrying steam-power traffic is to be obtained by blowing a current of air into one end of the tunnel for the purpose of removing, or of diluting and removing, the smoke and combustion gases at the opposite end. As practiced in America, this way of procuring ventilation partakes of two methods:

(a) To blow a current of air in the direction the train is moving and with sufficient velocity to remove the smoke and combustion gases ahead of the engine;

(b) To blow a current of air against the direction of the tonnage train with velocity and volume sufficient to dilute the smoke and combustion gases to such an extent as not to be uncomfortable to the operating crews and to clear the tunnel entirely within the minimum time limit for following trains.

[16]SPECIFICATIONS FOR USE OF VEGETATION FOR PROTECTION OF SLOPES AGAINST EROSION

(1) The slopes shall be graded to whatever final surface is desired.

(2) Vegetation suited to the conditions existing in the territory where slopes are to be protected, shall be selected. This may consist of sod transferred from other locations; sod grown on slopes, as a result of seeding; vines such as Honeysuckle, Myrtle, etc., and dwarf species of shrubbery.

(3) If the material of the slope is not fertile, it may be given a dressing of loam, manure, or commercial fertilizer. As manure generally contains weed seeds, care must be taken, where applied, to prevent troublesome weeds from going to seed.

(4) In order to prevent newly laid sod, transferred from other locations, from slipping, it is necessary to hold same to the slopes by use of wooden pins not less than seven (7) inches long, spaced not more than two (2) feet apart.

(5) A good seed mixture for well watered parts of the country consists of about 50 per cent alfalfa, 25 per cent Kentucky blue grass, and 25 per cent of red top seed. Care must be taken to inoculate the alfalfa seed, if the soil has not previously grown alfalfa. Sweet clover is also effective at many locations, and in some sections of the country Bermuda grass is found to be best.

(6) Honeysuckle vines are effective at many locations, recommended spacing of plants being two (2) feet apart.

(7) The following species of dwarf shrubbery may be used under certain conditions: Indian currant (*Symphoricarpos-Vulgaris*); Bittersweet-American; Forsythia (*Intermedia*).

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[15] Adopted, Vol. 15, 1914, pp. 339, 1034.

[16] Adopted, Vol. 28, 1927, pp. 841, 1454.

[17]MEANS FOR PREVENTION OR CURE OF WATER POCKETS IN ROADBED

(1) Water pockets have existed for many years in certain localities since construction.

(2) They have increased and become more noticeable since the use of heavier equipment and greater density of traffic.

(3) In water pockets the ballast has generally been beaten down into the roadbed and formed a trough under the track, the sub-ballast and roadbed being pushed out laterally and sometimes raised, forming walls, to prevent the water draining from under the track.

(4) Water pockets exist in fills as well as cuts, but more generally in cuts of a clayey nature.

(5) Water pockets exist in localities where soil conditions are unfavorable to satisfactory maintenance, particularly in clay.

(6) Method of surfacing and tamping track has no particular effect in forming water pockets, but the class of material used as ballast does have considerable effect.

(7) Water pockets can be prevented in many cases by proper formation of roadbed and use of proper kind and depth of ballast, as follows:

(a) Where roadbed, in either cuts or fills, is composed of a more or less clayey material, after the work has been brought to a subgrade, all construction tracks should be removed and the subgrade rolled with a road roller weighing about ten tons, to a uniformly smooth surface, with either sufficient crown or side slope to shed water; any resulting depression below subgrade being loosened up with a plow and brought up to subgrade by the addition of material of the same kind as that composing the roadbed; and then rerolled.

After several years' use under traffic it may be necessary to cut through the shoulder of the subgrade at frequent intervals to afford drainage, as the subgrade under the track will settle several inches lower than the shoulder.

(b) Sub-ballast should be of good cinder, stone screenings or other similar material, so as to prevent roadbed working up into the ballast proper. Stone ballast should not be used directly on top of clay or loam roadbed.

(c) Sufficient depth of ballast should be provided to insure even distribution of the load on the roadbed.

(d) Construction trains should not be run, if possible to avoid, over track laid on new roadbed without ballast. This drives the ties into the roadbed and forms depressions, which later on develop into water pockets.

(e) All drain tile, or underground drain pipes, should be covered 24 inches, or more, with engine cinders or equally porous material, and the remainder of the trench backfilled with material which is sufficiently porous to permit of good drainage.

(f) All roadbeds should have sufficient crown to drain properly and the surface should be smooth, and be maintained in this condition until the ballast is placed. Any backfilling necessary to make a smooth surface should be made of the same material as exists in the roadbed.

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[17] Adopted, Vol. 20, 1919, pp. 416, 880.

(g) In building new roadbed alongside existing tracks on same grades, care should be taken not to form new roadbed of impervious material at a higher elevation than the original roadbed, but the new roadbed should be kept at or below this level so as to provide an outlet for the drainage through the existing ballast. This is particularly important on hillside construction. If change in existing gradient is to be made, new roadbed for both tracks should be on the same level.

(8) In curing water pockets the principal object is to provide proper drainage. This may be accomplished, according to localities, in several ways, as follows:

(a) In cuts, by means of sub-soil drains of vitrified bell and sewer pipe, laid in ditch or between tracks with uncemented joints. They should be laid at such depth as to be below any movement of the subgrade and below the water to be drained. They should be below the frost line. Lateral drains of pipes or of cinder or stone may be made to tap the pockets if necessary. All pipes should be covered 12 inches or more with engine cinders or equally porous material, and then the trench be backfilled with the same material as removed, if at all porous, otherwise backfill with cinders.

(b) In cuts where material is very soft to a considerable depth, a drain about three feet square may be provided of large stone, either in the ditch line or between tracks, and of sufficient depth to take the drainage.

(c) In cuts where material is soft to a great depth, old ties or bridge timbers may be driven just outside the ends of the ties. These serve to hold the roadbed in place and to some extent lower the water level, leaving the top surface of the roadbed more firm.

(d) On fills, water pockets should be tapped by lateral ditches and filled with porous material so as to drain.

(e) In many cases the material will have to be excavated and a bed of old timber, cinder or other material spread over the surface to provide sufficient area to prevent the further penetration of the ballast into the roadbed, and the ballast should then be replaced with good, clean material.

[15]METHODS OF PREVENTING THE FORMATION OF WATER POCKETS UNDER THE BALLAST WHEN EMBANKMENTS ARE WIDENED AND/OR RAISED

When embankments are to be widened and/or raised, field studies should be made to determine the elevation of bottom of existing ballast, the filling material, if of impervious nature, to be kept below such ballast level and sloped outward. Any additional filling material needed to complete a higher roadbed section should consist of porous material.

In case porous material is not available for such higher section, longitudinal and cross drains are necessary, the type, sizes, spacing of cross drains, etc., to be determined by studies of each location. They should be laid at such depth as to be below any movement of the subgrade. Excavation for such drains must be taken out to below frost line, and made to proper grade. Subgrade should be laid to regular line and true grade, and covered with pervious material.

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[15] Adopted, Vol. 30, 1929, pp. 243, 1356.

[19]DRAINAGE OF ROADWAY THROUGH STATIONS AND YARDS

(1) The drainage of roadway through stations and yards should be treated in accordance with local conditions.

(2) Surface water should be carried off roadbed into drains as quickly as possible.

(3) Items influencing mode of procedure are: Soil condition, contour of adjacent ground, grade of tracks, number of tracks, amount of rainfall, etc.

(4) Surface water should be taken care of first by open ditches as much as possible, where they will not interfere with the work of employees or the safety of passengers.

(5) Where the subgrade is of such a nature that it will absorb water and not retain it, a sub-ballast of engine cinders should be used, the surface of which should not be allowed to become foul, but kept open so that water will penetrate the subgrade through the cinder. Where the subgrade will hold water, special effort should be made to carry it away from the subgrade by means of drains.

(6) Tracks in yards should be so constructed where practicable that tracks adjacent to main lines will be about two inches below them and each succeeding track stepped down to suit the normal trend of drainage, thus providing drainage laterally as well as longitudinally.

(7) Crossdrains, with catch-basins between tracks, should be placed where necessary.

(8) If the subsoil is of such a nature that it retains water and becomes saturated therewith, place bell and vitrified drain pipe or other drains with open joints between tracks, using special care to put them below frost and deep enough to get below the movement of the soil; these pipes running into crossdrains leading to natural drainage.

(9) If subsoil is silty or of such consistency as to quickly fill up the pipe, a wide ditch should be dug, preferably between tracks, and filled with large stone, having pipes leading off from it to the natural drainage.

(10) At station platforms a subdrain, with catch-basins at frequent intervals, should be laid alongside the curbing, or bell end vitrified pipe may be laid between tracks a sufficient depth to be below frost and movement of the soil. These drains to be connected by means of side drains to natural ditches, or in cuts to bell end vitrified subdrain laid in the ditch line.

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[19] Adopted, Vol. 19, 1918, pp. 407, 1181.

[20]SLOPES FOR HIGH ROCK CUTS OF FORTY FEET IN HEIGHT OR MORE

(1) Where the depth of ballast on Class A track is greater than 12 inches under the tie the adopted standard berm should be added to each side of the standard ballast section adopted for the increased depth of ballast. If the sum obtained by the addition of the standard berm to the distance of the toe of the ballast slope from the center of the track ends in a fractional part of a foot, the sum is to be increased or decreased to the nearest whole number of feet.

(2) Rock cuts of forty (40) ft. in height or more should be constructed at slopes of one-quarter to one.

(3) The advisable width for newly-constructed roadbed on high embankments of fifty (50) ft. or more by dumping from the trestle should be as follows (no allowance to be made in height):

Anticipated shrinkage 7 per cent, add 10 per cent of height to each shoulder.

Anticipated shrinkage 10 per cent, add 15 per cent of height to each shoulder.

Anticipated shrinkage 15 per cent, add 22.5 per cent of height to each shoulder.

[21]DRAINAGE OF LARGE CUTS

(1) More consideration should be given by Locating Engineers to probable drainage conditions in selecting a line contemplating long, low-grade cuts.

(2) If long, low-grade cuts are practically unavoidable, Construction and Maintenance Engineers should see that, where practicable, good wide, deep side ditches are provided and maintained.

(3) When not possible or practicable to handle drainage with wide, deep side ditches, subdrainage should be provided by installing blind rock drains or tiling, as it is impossible to maintain railway track in satisfactory condition unless water is kept drained away from, over, in, around or beneath the track.

[22]CONSTRUCTION MACHINERY

The use of steam shovels, locomotive cranes, dragline excavators, power ditchers, etc., is constantly increasing on railways; their construction needs to be given attention.

However, as most of such machinery is made by proprietory manufacturers it is not feasible to write definite specifications for their construction. In the purchase of such machines the following points should be given especial attention:

(1) Select machines each part of which is made of the kind and grade of material which is most suitable for that part, be sure that steel is used where steel is needed, special or alloy steels used where such material is best suited for the purpose, etc.

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[20] Adopted, Vol. 18, 1917, pp. 670, 1510.
[21] Adopted, Vol. 22, 1921, pp. 716, 1051.
[22] Adopted, Vol. 18, 1917, pp. 626, 1510; Vol. 27, 1926, pp. 769, 1403.

(2) Select a machine which is designed for strength and durability without sacrifice of serviceability.

(3) Select machines which are capable of maximum production.

(4) Select the type of machine which will best serve the conditions under which it is going to be used throughout its lifetime, unless a sufficiently large amount of special work is in sight to justify the purchase of a special machine for the job.

(5) Machines which are to be operated on tracks should, whenever practicable, be built to standard gage.

[23]OPERATORS OF STEAM SHOVELS AND KINDRED MACHINERY

The fundamental requirements for a successful operator are good judgment in handling loads, ability to keep work moving and care in maintaining the machine.

[24]SOFT SPOTS

Where soft spots cannot be effectively drained the bearing area of the track structure must be increased.

Definition of Soft Spot.—Soft spots are small areas in excavation or embankment, or the subsoil under an embankment, saturated with water and having a relatively small supporting power.

[25]DITCHING

(1) Good roadbed drainage is the foundation of economical track maintenance; therefore, the ditching of cuts is of great importance and should be carried out currently as part of the regular yearly maintenance program.

(2) Ditching, in ordinary material, may be subdivided into two principal classes:

Class "A"—Cuts not more than six feet deep in average open country.

Class "B"—Cuts more than six feet deep.

CLASS "A"—CUTS LESS THAN SIX FEET DEEP

(3) Company forces: On lines where traffic is heavy and ditching is done currently the work can usually be done economically by company forces, the material being cast out of the cut and leveled back so as to prevent it from washing down into the ditches. This method may also be economical on lighter traffic lines, where cuts are isolated and the volume of material to be moved is comparatively small.

(4) Contract forces; station men; teams and scrapers: These methods are found to be economical on lines of heavy traffic where, on account of deferred maintenance or nature of material, the volume to be handled is large. These methods may also be used to advantage on lighter

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[23] Adopted, Vol. 27, 1926, pp. 785, 1403.

[24] Adopted, Vol. 23, 1922, pp. 403, 1097.

[25] Adopted, Vol. 23, 1922, pp. 415, 1098.

traffic lines where conditions are favorable. In all cases where material is deposited on top of the cuts it should be leveled back to prevent washing down into the ditches.

(5) Spreader cars equipped with wings for shaping ballast shoulders, roadbed shoulders, ditches and slopes: These machines may be used to advantage on lines of moderate traffic in ordinary material.

CLASS "B"—CUTS MORE THAN SIX FEET DEEP

(6) Company forces provided with push cars and dump beds, wheelbarrows or trackbarrows. Loading and hauling out: This method will be found to be economical on heavy traffic lines, and also on lines with moderate traffic, where ditching machines are not available, or where the volume of material to be handled would not justify their use.

The use of work trains with hand labor is generally uneconomic, and is not recommended.

(7) Teams and scrapers on yardage basis: Where the character of material is suitable, and the volume to be handled comparatively large, teams and scrapers may be used to advantage under unit cost contract, provided the cuts are of sufficient width to permit of safe operation.

(8) Auxiliary track and small cars: This method may be used economically on heavy traffic lines where operating tracks cannot be interfered with and where there is sufficient clearance, provided the haul is long and volume of material to be handled would justify the initial cost of the plant installation.

DITCHING MACHINES

(9) There are a number of items and conditions which should be considered before undertaking work with ditching machines and their equipment—interest on investment, depreciation, upkeep, work train service and interruption to traffic are vital items which should not be overlooked. Equipment of this class has advantages which should also be taken into consideration. Ditching machines have a wide scope of operation; they will move large volumes of material in a comparatively short time; they make it practicable to utilize the material excavated for bank widening, trestle filling or other like work. The final consideration relative to use of ditching machines is density of traffic or frequency of trains.

The use of steam ditchers and their equipment is recommended in work where the cuts are long and deep, or where the volume of material to be moved is great; or where the material is wet and difficult to handle by other methods. Their use is also recommended where cuts are resloped or widened to such a limited extent as *not* to justify the use of steam shovel. Under similar conditions they may be used for widening embankments. They are particularly efficient in removing small slides or other like emergencies where material is wet or hard to handle.

Locomotive cranes equipped with clam-shell buckets one to one and one-half cubic yards' capacity can be used successfully in cleaning out cut ditches where it is desirable not to disturb the slopes and will produce a ditch of uniform width and depth without handling surplus material or requiring any redressing by hand. On account of the possibility of a considerably longer boom, this machine is more elastic in disposing of material, as it will even deposit material above grade on top of cut of medium depth. Under favorable circumstances it may be used without work train service, as it is self-propelling. Also, on account of the long boom, when equipped with orange-peel bucket, this machine can be used to advantage in cleaning out coarse material from cross ditches.

Where, on account of long haul in disposing of material, it is necessary to load many cars before dumping ditching equipment is recommended which will operate over a series of flat cars with a proper mechanical device or plow for unloading.

There may be isolated cases where it is economical to use scoop ditchers, but the steam ditcher or the locomotive crane will accomplish the same results with a greater flexibility.

(10) Work incidental to ditching such as shaping roadbed and ballast shoulders is primarily hand work after the major work of ditching is complete, but by the use of spreader cars with proper attachments this work may be done at a cost that is comparatively low and their use is recommended for these purposes when the nature of material will permit and where traffic conditions will not prohibit such interference.

[26]ECONOMICS OF FILLING BRIDGE OPENINGS

This subject is treated from the standpoint of a justification of expenditures. Before it can be determined whether the replacement indicates the filling of the bridge openings or some other method of replacement, a careful analysis of all the component elements of cost must be made. In many cases, no doubt, methods other than filling may be found preferable, but the general principles laid down are applicable to any bridge replacement problem. It is impossible to restrict it to the question of bridge filling alone. This discussion applies to any problem which involves economic comparisons between the renewing of a structure in kind and the replacing of it by a more permanent structure. Obviously, where a more permanent type of construction costs less than a renewal in kind, there can be no question as to the economy of making the improvement. Replacement or renewal of bridges and trestles takes place for one or more of the following reasons:

(1) **Obsolescence.**—In the case of a bridge, this will probably be due to heavier traffic or heavier equipment.

(2) **Deterioration** (natural decay or wear and tear, due to any cause).

(3) **Accident** (fire, wreck, flood or faulty design or construction, etc.).

The problem then resolves itself into whether it is more economical to fill, renew in kind or to replace with a more permanent type of structure at a greater investment outlay.

The question of full maturity should also be considered—care should be taken that the full life of the structure is obtained; as, for instance, a bridge that may safely last one or two years longer by an annual expenditure of an amount less than the interest and maintenance charges of new structure per year, should not be renewed or replaced until expiration of its full service life. The element of safety, including strength of structure and elimination of fire hazard, must be given consideration in all cases.

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[26] Adopted, Vol. 27, 1926, pp. 788, 1403.

In the case of bridge openings on main lines, consideration should be given to the possibility of future changes in grade and alinement, and in estimating the life of the replacement structure or fill, this should be taken into account. Similarly, on branch lines traffic conditions should be investigated and any evidence of ultimate abandonment, either from depletion of natural resources or on account of competitive conditions, should not be overlooked in estimating the life of the new structure or the fill. When there is any occasion for doubt, low estimate of life should be made, and when the difference in annual cost favors the more permanent structure or fill by only a relatively small amount, preference should usually be given to the less permanent structure.

The problem is illustrated by analyzing the relative economy of renewing a 42-ft. pile trestle having an average life of 7 years, as compared with replacing it by a double 6 ft. by 10 ft. concrete box culvert and fill with estimated life cycle of 70 years.

The annual amortization charges are determined on the sinking fund basis.

The formula for this determination is:

$$\frac{P\text{ (Principal)} \times r\text{ (Interest rate)}}{(1+r)^n - 1} = \text{Annual Amortization charge.}$$

^{n} = life in years.

In the first example shown in the "Analysis of Costs" the Principal is 722, the rate is 6 per cent, and the life is 7 years.

$$\text{Then } \frac{\$722 \times 0.06}{(1+0.06)^7 - 1} = \frac{\$43.32}{0.504} = \$86.01$$

which is the amortization charge for the existing structure and represents a portion of the $168.33 in Column 9.

For the proposed structure a life of 70 years is assumed.

$$\text{Then } \frac{\$119.28}{58.08} = \$2.05.$$ This is a portion of the $129.33 in Column 17.

For convenience in determining this charge, a table of the values of $(1+r)^n - 1$ is given below.

If the life of the proposed structure may be assumed to be perpetual, then the amortization charges will be zero; but it is not reasonable to assume that any physical structure will have a perpetual life. However, if the life may be assumed to be so long that it is impossible at the time of construction to estimate whether it may be in excess of one hundred years (or so-called permanent) it seems proper to postpone the setting aside of an amortization fund until such time as the expected life may be estimated within reason. In fact, it is a question whether attempts should be made to estimate life in excess of, say, 50 years.

It also should be borne in mind that cost estimates are seldom sufficiently exact to warrant undue nicety in calculations. In short, good engineering is largely the application of good judgment to a problem after consideration is given to all the data available. There often is a great deal of data which is of very little value and to which small consideration need be given.

ANALYSIS OF COSTS—PRESENT AND PROPOSED STRUCTURES

Existing Conditions (Renewal)

1	2	3	4	5	6	7	8	9
	Center Line Length, Description and Established Life Cycle	Cost of Renewing in Kind	Cost of Maintaining Traffic During Renewal	Total Cost of Renewal in Kind	Annual Interest on Total Renewal Cost at 6%*	Annual Cost of Repairs and Maintenance	Annual Amortization Charge on Sinking Fund Based at 6%*	Total Annual Cost, Interest, Maintenance and Amortization Charge
79	42 ft. pile trestle, 7 years..........	$640.00	$82.00	$722.00	$43.32	$39.00	$86.01	$168.33
82	76 ft. frame trestle, 9.2 years......	1140.00	135.00	1275.00	76.50	60.00	107.85	244.35
76	112 ft. ballast deck trestle, 19.6 years..........................	1758.00	180.00	1938.00	116.28	55.00	54.51	225.79

TABLE OF VALUES OF $(1+r)^n - 1$ ON 6 PER CENT BASIS

$(1+0.06)^n - 1$

$^n =$ life in years

n Yrs	(1.06)n—1	n Yrs	(1.06)n—1	n Yrs	(1.06)n—1	n Yrs	(1.06)n—1	n Yrs	(1.06)n—1	n Yrs	(1.06)n—1
2	0.12360	9	0.68948	16	1.54035	26	3.54939	45	12.7647	80	104.80
3	0.19102	10	0.79085	17	1.69277	28	4.11170	50	17.4202	85	140.58
4	0.26248	11	0.89830	18	1.85434	30	4.74351	55	23.650	90	188.47
5	0.33823	12	1.01220	19	2.02560	32	5.45340	60	31.988	100	338.3
6	0.41852	13	1.13293	20	2.20714	34	6.25115	65	43.145	110	606.6
7	0.50363	14	1.26090	22	2.60354	36	7.14728	70	58.076	125	1455.3
8	0.59385	15	1.39656	24	3.04894	40	9.2855	75	78.057	150	6249.0

As a general outline by which the relationships between the various elements of cost may be analyzed, the following method of procedure is recommended (see tabulation of examples):

Identification—Column 1—Identification of Structure.

Existing Condition (Renewal).

Column 2—Center line length, type and established life cycle of structure. The established life cycle in years is usually obtainable from major renewals. In other cases where renewals are continuous, this period may be arrived at approximately by dividing the cost of a complete new structure in kind by the average annual costs of piecemeal structural renewals.

ANALYSIS OF COSTS—PRESENT AND PROPOSED STRUCTURES

Proposed Conditions (Replacement)								Determining Factor		Replacement Accounting		
10	11	12	13	14	15	16	17	18		19	20	21
Type of Proposed Structure and Estimated Life Cycle	Cost of Proposed New Structure	Cost of Maintaining Traffic During Replacement	Total Cost to Replace	Annual Interest on Total Replacement Cost at 6%*	Annual Cost of Repairs and Maintenance	Annual Amortization Charge on Sinking Fund Basis 6%*	Total Annual Cost, Interest, Maintenance and Amortization Charge	Annual Gain or Loss by Replacement		Charge to Operating Expenses		Charge to Investment "A" or "B" or Both
								+	−	Maintaining Traffic During Construction	Property Retired and Replaced	
Double 6 ft.x10 ft. concrete box and fill. 70 years.	$1799.00	$189.00	$1988.00	$119.28	$8.00	$2.05	$129.33	$39.00	....	$189.00	$640.00	$1159.00
Double 8 ft. x 8 ft. concrete box and fill, 100 years.	$3685.00	$430.00	$4115.00	$246.90	$15.00	$0.73	$262.63	....	$18.28	$430.00	$1140.00	$2545.00
80 ft. deck plate girder on concrete abutments and fill 75 years	$12850.00	$80.00	$12930.00	$775.80	$60.00	$9.94	$845.74	....	$615.95	$80.00	$1758.00	$10992.00

*Each railroad to use the rate of interest it deems proper

Column 3—Cost of renewing in kind (Engineer's estimate).

Column 4—Cost of maintaining traffic during renewal (Engineer's estimate).

Column 5—Total cost of renewing in kind (sum of $640.00 plus $82.00 = $722.00). The sum of Columns 3 and 4.

Column 6—Annual interest on total cost of renewal (6 per cent of $722.00 = $43.32).

Column 7—Annual cost of repairs and maintenance (546.00 ÷ 14 = $39.00).

This $546.00 is the sum of the maintenance and repairs for two life cycles taken from the maintenance records and adjusted to current prices. It should contain all costs for insurance, labor and materials, and interest, depreciation and repairs on tools and equipment.

Column 8—Annual amortization charge on sinking fund basis at 6 per cent.

$$\frac{\$722.00 \times 0.06}{(1 + 0.06)^{7} - 1} = \frac{\$43.32}{0.50363} = \$86.01$$

When the life cycle contains fractional years, as in the second **example,**

$$(1 + 0.06)^{9.2} - 1 = 0.7093$$

$$\text{Log}\quad 1.06 = 0.0253059 \times 9.2 = 0.232814 = \log 1.7093$$

$$1.7093 - 1 = 0.7093$$

$$\text{Then}\ \frac{\$1275.00 \times 0.06}{(1.06)^{9.2} - 1} = \frac{\$76.50}{0.7093} = \$107.85.$$

In the third example — $(1 + 0.06)^{19.6} - 1 = 2.133.$

$0.0253059 \times 19.6 = .495996 = \log 3.133.$

$3.133 - 1 = 2.133.$

$$\text{Then}\ \frac{\$1938.00 \times 0.06}{(1.06)^{19.6} - 1} = \frac{\$116.28}{2.133} = \$54.51.$$

Column 9—Total annual cost, interest, maintenance and amortization charge. (The sum of Columns 6, 7 and 8.)

PROPOSED CONDITIONS—(REPLACEMENT)

Column 10—Type of proposed structure and estimated life cycle.

Column 11—Cost of proposed new structure (Engineer's estimate).

Column 12—Cost of maintaining traffic during replacement (Engineer's estimate).

Column 13—Total cost to replace (the sum of $1799.00 plus $189.00 = $1988.00, Column 11 plus Column 12).

Column 14—Annual interest on total cost of replacing ($1988.00 at 6 per cent = $119.28).

Column 15—Annual cost of repairs and maintenance (Engineer's estimate).

Column 16—Annual amortization charge on sinking fund basis at 6 per cent for total cost of replacing:

$$\frac{\$1988.00 \times 0.06}{(1 + 0.06)^{70} - 1} = \frac{\$119.28}{58.08} = \$2.05$$

The 58.08 is taken from the table of values of $(1 + r)^{n} - 1$ for 70-year life cycle.

Column 17—Total annual cost, interest, maintenance and amortization charge (the sum of Columns 14, 15 and 16).

Determining Factor

Column 18—Annual gain or loss by replacement. Difference between $168.33 in Column 9 and $127.33 in Column 17, which show a net annual saving of $39.00 by providing new structure over the old structure. Where the result shows a loss or deficit, consideration should be given to operating advantages which may offset loss by replacement.

ACCOUNTING

Columns 19 and 20—Charges to operating expenses:

(a) Maintaining traffic during construction—taken from Column 12. This is always an operating charge.

(b) Property retired and replaced, taken from Column 3. This is usually an operating charge, but under special circumstances may be charged to profit and loss. (See page 13, Section 7, I. C. C. Classification of Investment.)

Column 21—Charges to investment (additions or betterment or both). This is the net additional investment—difference between Column 20 and Column 11, or $1799.00—$640.00 = $1159.00.

Columns 19, 20 and 21 show the accounting distribution of the entire cost of replacement.

[27]SPECIFICATIONS FOR METAL FENCE POSTS

Classes

Metal fence posts shall be divided into two classes:

(1) Posts which support the straightaway body of the fence shall be designated as "line posts."
(2) Such other special posts as are needed at the end or corner of the fence and at gates, shall be designated as "end, corner, and gate posts."

Material

Metal fence posts may be made of steel or wrought iron, or alloys of iron of any kind which will pass strength tests as described below.

Strength

Material used for fence posts shall have a minimum tensile strength of 40,000 lb. per sq. in., and with a finished post, clamped rigidly, a load of 300 lb., applied at three feet from the face of the clamp, the deflection shall not exceed six inches and the permanent set shall not exceed two and one-half inches. The load for this test shall be applied to the face of the post against which the fence material bears.

Ductility

A finished post resting upon supports five feet apart, and with a load applied at the center, must withstand bending nine inches from a straight line, with no signs of failure.

TUBULAR POSTS.—The cold rolling of tubular posts is sufficient test for ductility, therefore tubular posts are exempt from the ductility test.

Workmanship

All posts shall be smoothly rolled or formed and shall be straight throughout the length. Each finished post shall be free from burrs or other deformation caused by fabrication. They shall also be free from slivers, depressions, seams, crop ends and evidence of being burnt. (The above does not refer to rough places caused by zinc coating when galvanized.)

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[27] Adopted, Vol. 29, 1928, pp. 546, 1394.

Variations in length shall not exceed one-half inch over or under the prescribed length. Variations in other dimensions shall not be more than one-sixteenth inch over or under the prescribed figures.

Coating

ZINC.—All galvanized posts shall be galvanized by the hot dip process and shall possess a uniform coating of Prime Western spelter or better grade, with not less than two ounces per square foot of surface as determined by the spot test or by the Preece Test with four dips.

Galvanized posts are to be desired. All posts not galvanized shall be painted or dipped in a protective coating of metallic paint.

Special Fabrication for Line Posts

Line posts shall be fabricated to the section agreed upon by the purchaser.

If the posts are not so designed as to make anchorage for alinement unnecessary, an anchorage device shall be rigidly fabricated to bottom portion of posts.

All posts shall be provided with some convenient means of fastening wire to same for at least 12 positions in a height of five feet, above the surface of the ground. All posts shall permit the refastening of the wire at least five times without damage to the connecting appliance, if an integral part of the post.

All posts shall be capable of being driven in ordinary earth without injury to the post.

All posts shall have sufficient length so that when installed with the required height above ground, one-third of the total length shall be underground, providing that the post shall extend into the ground not less than 2½ feet.

Special Fabrication for End, Corner and Gate Posts

All special posts shall be fabricated the same as line posts, except as follows:

All posts shall have sufficient length to permit installing 3 feet into the ground; and shall be equipped with some suitable form of bracing and anchorage which shall aid in keeping the post vertical.

Weight

The main stem of all form sections, not including tubing, shall weigh at least 1.30 pounds per linear foot, and preferably should be 25 per cent heavier than that. Posts made of tubing shall be fabricated of at least ten gage material and be not less than 1¾ inches in diameter.

Inspection

Inspection and approval of the posts shall be made by the Engineer or other authorized representative of the purchaser. Such inspection shall be made at the plant of the manufacturer, who will allow the inspector access to all operations involved and shall facilitate as much as possible the work of inspection and provide necessary facilities for inspection. Two posts out of each 200, selected by the inspector at random, shall be inspected and tested and if they meet the requirements, the lot shall be accepted. If either fails to meet requirements, three other posts shall be selected in like manner by the inspector, and if either one of these shall fail, the lot shall be rejected.

SIGNS, FENCES AND CROSSINGS

Explanatory Note.—The former Committee on Signs, Fences and Crossings was abolished in 1926, by action of the Board of Direction, and the scope of work transferred to Committee I—Roadway, with the exception of Highway Crossing Signs and Specifications for Highway Grade Crossings, which have been retained in the subject-matter coming under the jurisdiction of Committee IX—Grade Crossings.

[1]DEFINITIONS

FENCES

FENCE.—A barrier that serves to guard against unrestricted ingress or egress, generally a line of posts with rails or wire, or rails and vertical boards or pickets.

POST.—A piece of wood, metal or other material, set upright and used to support the longitudinal members of a fence.

END POST.—A post at the end of a line or section of fence.

CORNER POST.—A post located at the intersection of two lines or sections of fence.

ANCHOR POST.—A post located between end or corner posts and used as an anchor for stretching wire.

INTERMEDIATE OR LINE POST.—A post placed between end or corner posts.

RAIL.—Any longitudinal member of a fence other than wire.

CLEAT.—A piece of wood, metal or other material, fastened transversely to the side of a post below the ground to give it greater stability.

BRACE.—A piece of wood, metal or other material, in compression, placed diagonally between adjacent posts.

TIE.—A piece of wood, metal or other material, in tension, between adjacent posts.

PANEL.—A section of fence between two adjacent posts.

BRACE PANEL.—A panel in which a brace or tie, or both, are introduced.

STAY.—A piece of wood, metal or other material, used to stiffen the fence and to maintain the spacing of the longitudinal wires.

STAPLE.—A metal device in the shape of a letter "U" with sharpened ends for fastening the longitudinal wires of the fence to the posts.

GATE.—A movable barrier consisting of a structure of wood, metal or other material, for closing a passageway or an opening in a fence.

GATE FRAME.—The sustaining part of a gate, fitted and framed together, to which the other members are attached.

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[1] Adopted, Vol. 5, 1904, pp. 381, 382, 386, 390, 446-451, 458, 459; Vol. 6, 1905, pp. 781, 782; Vol. 7, 1906, pp. 458, 479; Vol. 10, Part 1, 1909, pp. 885. 915-917; Vol. 11. Part 2, 1910, pp. 1230, 1231, 1246; Vol. 16, 1915, pp. 435, 436, 1039-1041; Vol. 25, 1924, p. 624; Vol. 26, 1925, p. 1407.

Gate Brace.—A piece of wood, metal or other material, in compression, placed diagonally and used to stiffen the frame of a gate.

Gate Tie.—A piece of wood, metal or other material, in tension, placed diagonally and used to stiffen the frame of a gate.

Gate Post.—A post on which a gate is carried or to which it is latched.

Snow Fence.—A structure erected for the purpose of forming artificial eddies on the windward side of a cut at sufficient distance away to cause snow to deposit between the snow fence and the cut.

SURFACE STOCK-GUARDS

Stock-Guard.—A barrier of wood, metal or other material placed between and alongside of track rails to prevent the passage of live stock on or along the railroad track or tracks.

Slat.—A strip of wood, metal or other material used in making up a surface stock-guard.

Filler.—A piece of wood, metal or other material placed between the slats to space and stiffen them.

Apron.—A flared panel of fence set parallel with the track and along outside edge of a stock-guard.

Wing Fence.—A fence connecting the apron of the stock-guard with the right-of-way or line fence.

*CROSSINGS—BITUMINOUS MATERIALS

Bitumens.—Mixtures of native or pyrogenous hydrocarbons and their non-metallic derivatives, which may be gases, liquids, viscous liquids or solids, and which are soluble in carbon disulphite.

Asphalts.—Solid or semi-solid native bitumens, solid or semi-solid bitumens obtained by refining petroleum, or solid or semi-solid bitumens, which are combinations of the bitumens mentioned with petroleums or derivatives thereof, which melt upon application of heat and which consist of a mixture of hydrocarbons and their derivatives of complex structure.

Refined Asphalt.—Any asphalt which has been subjected to a refining process.

Asphalt Cement.—A fluxed or unfluxed asphaltic material, especially prepared as to quality and consistency, suitable for direct use in the manufacture of asphaltic pavements, and having a penetration of between 5 and 250.

Flux.—Bitumens, generally liquid, used in combination with harder bitumens for the purpose of softening the latter.

Penetration.—The consistency of a bituminous material expressed as the distance that a standard needle vertically penetrates a sample of the material under known conditions of loading, time and temperature.

Tars.—Bitumens which yield pitches upon fractional distillation and which are produced as distillates by the destructive distillation of bitumens, pyrobitumens or organic materials.

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*These definitions adopted from the American Society for Testing Materials.

REFINED TAR.—Tar freed from water by evaporation or distillation which is continued until the residue is of desired consistency; or a product produced by fluxing tar residuum with tar distillate.

PITCHES.—Solid residues produced by the evaporation or distillation of bitumens, the term being usually applied to residues obtained from tars.

EMULSIFIED ASPHALT.—An asphalt cement which has been combined with a small amount of soap forming constituents and water, so as to make the resulting mixture fluid at ordinary temperatures.

CUT-BACKS.—Petroleum or tar residuums which have been fluxed with distillates.

ROCK ASPHALT.—Sandstone or limestone naturally impregnated with asphalt.

[2]SPECIFICATIONS FOR STANDARD RIGHT-OF-WAY FENCES

Classes

1. Standard right-of-way fences shall be divided into four classes, the height to conform to statutory requirements, generally about 4 feet 6 inches above the ground.

Class A Fence

2. Class A fence shall consist of nine longitudinal smooth galvanized steel wires; the top and bottom wires shall be No. 7 gage; the intermediate and stay wires shall be No. 9 gage.

The spacing of the longitudinal wires (commencing at the bottom) shall be 4, 4½, 5, 5½, 6, 7, 8 and 9 inches. The bottom wires shall be five inches above the ground and the stay wires shall be spaced 12 inches apart.

When used as a hog-tight fence, a strand of barbed wire shall be added 2½ inches below the woven wire.

Class B Fence

3. Class B fence shall consist of seven longitudinal smooth galvanized steel wires; the longitudinal and stay wires shall be No. 9 gage.

The spacing of the longitudinal wires, commencing at the bottom, shall be 6½, 7, 7½, 8, 8½ and 9 inches. The bottom wire shall be seven inches above the ground and stay wires shall be spaced 12 inches apart.

Class C Fence

4. Class C fence shall consist of woven wire fencing 25½ inches high with three strands of barbed wire above. The woven wire fencing shall consist of seven longitudinal, smooth galvanized steel wires. The longitudinal and stay wires shall be No. 9 gage and the stay wires shall be 12 inches apart. The spacing of the longitudinal wires, commencing at the bottom, shall be 3, 3½, 4, 4½, 5 and 5½ inches, and the bottom wire shall be 2 inches above the ground. The spacing of the barbed wires above the woven wire shall be 4½, 10 and 12 inches.

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[2] Adopted, Vol. 5, 1904, pp. 386-390, 458, 459; Vol. 7, 1906, pp. 451-456, 478; Vol. 11, Part 2, 1910, pp. 1231-1234, 1246; Vol. 16, 1915, pp. 436-443, 1040; Vol. 22, 1921, pp. 269, 997; Vol. 25, 1924, pp. 622, 1331; Vol. 27, 1926, pp. 399, 1319.

Class D Fence

5. Class D fence shall consist of five strands of galvanized steel ribbon, smooth, round or barbed wire fencing.

The spacing of the wires, commencing at the bottom, shall be 10, 10, 12 and 12 inches. The bottom wire shall be ten inches above the ground.

The longitudinal wires of all woven wire fencing under Classes A, B and C shall be provided with tension curves to take up expansion and contraction.

MATERIAL

Wood Posts

6. Posts shall be made of cedar, locust, chestnut, Bois d'Arc, white oak, mulberry, catalpa or other durable wood native to the locality or of treated timber. They shall be straight and free from splits, rot or other defects.

If sawed or split posts are used, their dimensions shall be at least equal to those hereinafter specified for round posts.

End Posts, Etc.

7. End, corner, anchor and gate posts shall be at least 8 feet long and 8 inches in diameter at the small end, set 3 feet 4 inches in the ground.

Intermediate Posts

8. Intermediate or line posts shall be at least 7 feet long and 4 inches in diameter at the small end, set 2 feet 4 inches in the ground.

Braces

9. Braces for end, corner, anchor and gate posts shall be made of intermediate or line posts or 4 inch by 4 inch sawed lumber of a quality equal in durability to that of the posts, and free from large knots, splits, rot and other defects.

Wire

10. Woven wire fences shall be constructed of basic open-hearth galvanized steel wire. It must stand, without sign of fracture, winding tight around wire of the same size.

Wire for fencing shall have minimum ultimate tensile strength after galvanizing, as follows:

Line wire No. 7 gage	2200 lb.
Line wire No. 9 gage	1500 lb.
Line wire No. 12½ gage	700 lb.
Stay wire No. 9 gage	1100 lb.

Locks

11. The locks or fastenings at the intersection of the longitudinal and stay wires shall be of such design as will prevent them from slipping either longitudinally or vertically.

Staples

12. The staples used for fastening the longitudinal wires to the posts shall be made of No. 9 galvanized steel wire. They shall be 1 inch long for hardwood and 1½ inches long for softwood.

Galvanizing

13. The galvanizing shall consist of an even coating of zinc, which shall withstand four one-minute immersion tests in a solution of commercial sulphate of copper crystals and water, the specific gravity of which shall be 1.185 and whose temperature shall be from 60 to 70 degress Fahr. Immediately after each immersion the sample shall be washed in water and wiped dry. If the zinc is removed, or a copper-colored deposit formed at the end of the fourth immersion, the lot of material from which the sample is taken shall be rejected.

Manufacture

14. The fence shall be so fabricated as not to remove the galvanizing or impair the tensile strength of the wire.

ERECTION

End, Corner, Anchor and Gate Posts

15. End, corner, anchor and gate posts shall be set vertical, at least 3 feet 4 inches in the ground, thoroughly tamped, braced and anchored. In long runs of fence, anchor posts shall be spaced not more than one-quarter mile apart.

Intermediate or Line Posts

16. Intermediate or line posts shall be set at least 2 feet 4 inches in the ground and not more than 20 feet apart, center to center. The first line post from any corner, anchor or gate post shall be set 10 feet, center to center, from the same.

Post Holes

17. Holes of full depth shall be provided for all end, corner, anchor and gate posts, even if blasting must be resorted to. For intermediate or line posts, where rock is encountered, not more than two adjacent wood posts shall be set on sills 6 inches by 6 inches by 4 feet long, braced on both sides by 2 inch by 6 inch braces, 3 feet long. Holes shall be provided for all other posts. Posts shall be set with large end down and in perfect line on the side on which the wire is to be strung. After the fence is erected, the tops of the wood posts shall be sawed off with a one-fourth pitch, the high side being next the wire and 2 inches above it.

Anchoring

18. Wood end, corner, anchor and gate posts shall be anchored by gaining and spiking two cleats to the side of the posts, at right angles to the line of the fence, one at the bottom, the other just below the surface of the ground. The cleat near the ground surface shall be put on the side next the fence and the bottom cleat shall be put on the opposite side. Intermediate wood posts set in depressions of the ground shall be anchored by gaining two cleats into the side near the bottom of the post, same to be properly spiked.

Cleats, Sills, Etc.

19. All cleats shall be 2 inches by 6 inches by 2 feet long. All sills, braces and cleats shall be made of sawed lumber of a quality equal in durability to that of the posts.

Bracing

20. Wood end, corner, anchor and gate posts shall be braced by using an intermediate or line post or a piece of 4 inch by 4 inch sawed lumber of a quality equal in durability to that of the posts, gained into the end, corner, anchor or gate post, about 12 inches from the top and into the next intermediate or line post about 12 inches from the ground and be securely spiked. A cable made of a double strand of No. 9 galvanized soft wire looped around the end, corner, anchor or gate post near the ground line, and around the next intermediate or line post about 12 inches from the top, shall be put on and twisted until the top of the next intermediate or line post is drawn back about 2 inches.

Stretching

21. Longitudinal wires shall be stretched uniformly tight and parallel; stays shall be straight, vertical and uniformly spaced. Wires shall be placed on the side of the post away from the track, except that on curves of one degree or more the wires shall be placed on the side of the post away from the center of the curve.

Stapling

22. Staples shall be set diagonally with the grain of the wood and driven home tight. The top wires shall be double stapled.

Splicing

23. Approved bolt clamp splice or a wire splice made as follows may be used: The ends of the wires shall be carried 3 inches past the splicing tools and wrapped around both wires backward from the tool for at least five turns, and after the tool is removed, the space occupied by it shall be closed by pulling the ends together.

[3]GATES FOR RIGHT-OF-WAY FENCES

(1) A hinged metal gate is recommended.

(2) The width of farm gates should be not less than 12 feet, depending upon the size of agricultural machinery in use in the vicinity, or as required by the laws of the States through which the railway operates. The minimum height of farm gates should be 4 feet 6 inches from the surface of the roadway.

(3) Farm gates should be hinged so as to open away from the track, and, if hinged, swing shut by gravity, and the end of the gate opposite the hinged end should lap by the post a sufficient distance to prevent it from being opened by side pressure.

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[3] Adopted, Vol. 8, 1907, pp. 528, 533; Vol. 10, 1909, Part 2, pp. 876, 910; Vol. 11, 1910, Part 2, pp. 1234, 1246; Vol. 16, 1915, pp. 440, 1140; Vol. 27, 1926, pp. 399, 1319.

Table Showing Quantity of Material Needed for Barbed Wire and Board Fences

Spacing of Posts	Posts			Staples									Nails					
	Posts—No. Required			Staples Required in Pounds—1 Strand of Wire									Nails Required in Pounds—1 Board					
	Per Rod	Per 100 ft.	Per Mile	Per Rod			Per 100 feet			Per Mile			Per Rod		Per 100 feet		Per Mile	
				1 in.	1¼ in.	1½ in.	1 in.	1¼ in.	1½ in.	1 in.	1¼ in.	1½ in.	8d Com.	10d Com.	8d Com.	10d Com.	8d Com.	10d Com.
8	2.06	12.50	660.0	0.02	0.03	0.03	0.12	0.15	0.18	6.41	7.96	9.57	0 07	0.10	0.39	0.60	20.7	31.5
10	1.65	10.00	528.0	0.02	0.02	0.03	0.10	0.12	0.15	5.13	6.36	7.66	0.07	0.11	0.41	0.64	22.0	33.5
12	1.38	8.33	440.0	0.02	0.02	0.02	0.08	0.10	0.13	4.28	5.30	6 38	0.06	0.09	0.35	0.53	18.3	28.0
14	1.18	7.16	378.0	0.02	0.02	0.02	0.07	0.09	0.11	3.68	4.56	5.48	0.05	0.08	0.30	0.46	15.7	24.0
16	1.03	6.25	330.0	0.01	0.02	0.02	0.06	0.08	0.10	3.20	4.00	4.78	0 05	0.07	0.26	0.40	13.7	21.0
16½	1.00	6.06	320.0	0.01	0.02	0.02	0.06	0.08	0.09	3.11	3.86	4.64						
18	0.92	5.57	294.0	0.01	0.02	0.02	0.06	0.07	0.08	2.86	3.54	4.26						
20	0.83	5.00	264.0	0.01	0.01	0.02	0.05	0.06	0.07	2.56	3.18	3.83						

NOTE—The quantity of nails required is figured on a basis of two nails to a board to each post.

Where posts are 8 feet apart it is figured to use a board 16 feet long.

Barbed Wire Fencing

Style of Wire		Gage of Strand	Spacing of Barbs	Weight in Pounds		
				Per Rod	Per 100 Ft.	Per Mile
Baker's Perfect	Regular or Cattle, 2 pt	12½	5 in.	0.88	5.31	280.0
“ “	Thickset or Hog, 2 pt	12½	3 “	0.97	5.87	310.0
Ellwood	Regular or Cattle, 4 pt	12½	5 “	0.94	5.68	300.0
“	Thickset or Hog, 2 pt	12½	3 “	1.00	6.06	320.0
Ellwood Glidden	Regular or Cattle, 2 pt	12½	5 “	0.92	5.60	295.0
“ “	Thickset or Hog, 2 pt	12½	3 “	0.99	5.97	315.0
Ellwood Junior	Regular or Cattle, 2 pt	12½	5 “	0.88	5.31	280.0
“ “	Thickset or Hog, 2 pt	12½	3 “	0.94	5.68	300.0
American Glidden	Regular or Cattle, 2 pt	12	5 “	1.00	6.06	320.0
“ “	Thickset or Hog, 2 pt	12	3 “	1.08	6.54	345.0
Lyman	Regular or Cattle, 4 pt	12	6 “	1.14	6.92	365.0
“	Thickset or Hog, 4 pt	12	4 “	1.25	7.58	400.0
Waukegan	Regular or Cattle, 2 pt	12½	5 “	0.87	5.26	277.5
“	Thickset or Hog, 2 pt	12½	3 “	0.94	5.68	300.0
“	Regular or Cattle, 4 pt	12½	5 “	0.964	5.84	308.3
“	Thickset or Hog, 4 pt	12½	3 “	1.066	6.46	341.1
American Special	Regular or Cattle, 2 pt	14	5 “	0.630	3.82	201.7
“ “	Thickset or Hog, 2 pt	14	3 “	0.667	4.04	213.3

Board Fencing

Size of Board	Ft. B.M.		
	Per Rod	Per 100 ft.	Per Mile
1 in. x 4 in.	5.50	33.33	1760.0
1 x 6	8.25	50.00	2640.0
1 x 8	11.00	66.67	3520.0
1 x 10	13.75	83.34	4400.0
1 x 12	16.50	100.00	5280.0

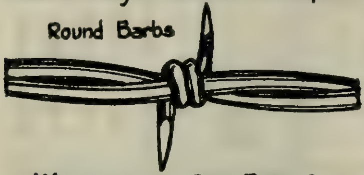
NOTE—The material given in the above tables is for one wire or one board high, in order that the material for fences of any number of wires or boards may be figured for different styles of wire and different sizes of boards.

Table includes an allowance of 5 per cent for loss of staples and 10 per cent for loss of nails.

BARBED WIRE FENCING

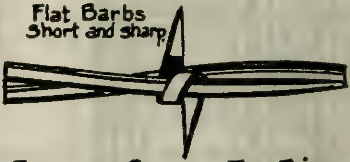
AMERICAN GLIDDEN-TWO POINT

Regular or Cattle – Barbs 5 inches apart.
Thickset or Hog – Barbe 3 inches apart.



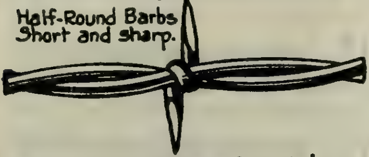
BAKER PERFECT-TWO POINT

Regular or Cattle – Barbs 5 inches apart.
Thickset or Hog – Barbs 3 inches apart.



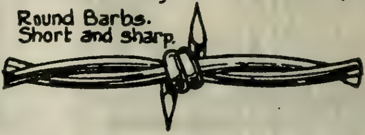
WAUKEGAN-TWO POINT

Regular or Cattle – Barbs 5 inches apart.
Thickset or Hog – Barbs 3 inches apart.



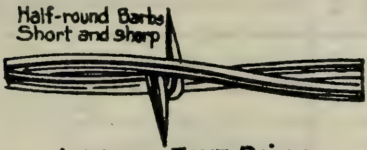
ELLWOOD GLIDDEN-TWO POINT

Regular or Cattle – Barbs 5 inches apart.
Thickset or Hog – Barbs 3 inches apart


Round Barbs.
Short and sharp.

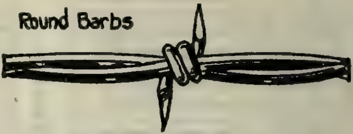
ELLWOOD JUNIOR-TWO POINT

Regular or Cattle – Barbs 5 inches apart.
Thickset or Hog – Barbs 3 inches apart.



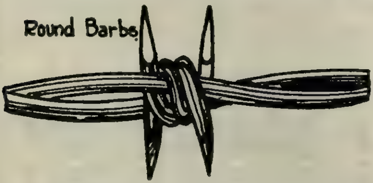
AMERICAN SPECIAL-TWO POINT

Regular or Cattle – Barbs 5 inches apart.
Thickset or Hog – Barbs 3" inches apart.



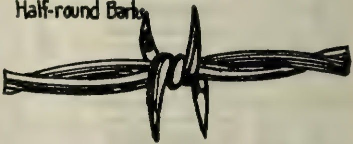
LYMAN – FOUR POINT.

Regular or Cattle – Barbs 6" inches apart.
Thickset or Hog – Barbs 4" inches apart.



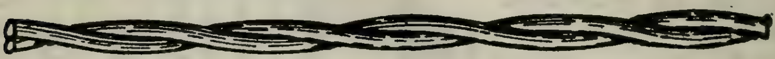
WAUKEGAN – FOUR POINT

Regular or Cattle – Barbs 5 inches apart.
Thickset or Hog – Barbs 3 inches apart.

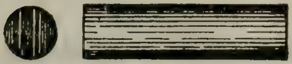
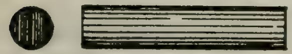
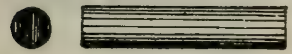
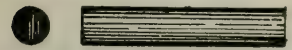
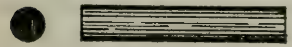
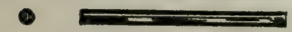


BARBLESS FENCING

Two-Ply Twisted Galvanized Barbless Fencing. Sizes 8 to 14 inclusive. 3 Ply, 4 Ply, 5 Ply and 6 Ply Twisted Barbless Fencing. Sizes 8 to 14 iclusive.



SMOOTH WIRES

Cuts show exact sizes of No. 1 to No. 20 gage steel wire by American Steel & Wire Co.	Gage	Diameter in inches	Lb. to Mile	Lb. to Foot	Feet to 1 lb.
	1	.2830	1128.00	0.2136	4.481
	2	.2625	970.40	0.1838	5.441
	3	.2437	836.40	0.1584	6.313
	4	.2253	714.80	0.1354	7.386
	5	.2070	603.40	0.1143	8.750
	6	.1920	519.20	0.0983	10.170
	7	.1770	441.20	0.0835	11.970
	8	.1620	369.60	0.0700	14.290
	9	.1483	309.70	0.0586	17.050
	10	.1350	256.70	0.0486	20.570
	11	.1205	204.50	0.0387	25.820
	12	.1055	156.70	0.0296	33.690
	13	.0915	117.90	0.0223	44.780
	14	.0800	90.13	0.0170	58.580
	15	.0720	73.01	0.0138	72.320
	16	.0625	55.00	0.0104	95.980
	17	.0540	41.07	0.0077	128.600
	18	.0475	31.77	0.0060	166.200
	19	.0410	23.67	0.0044	223.000
	20	.0348	17.05	0.0032	209.600

[4]CONCRETE FENCE POSTS

Concrete fence posts are practical, economical and a suitable substitute for wood.

[5]SPECIFICATIONS FOR CONCRETE FENCE POSTS

(I) MATERIALS

Intent

1. The intent of these specifications and the plans of which they form a part is to produce concrete fence posts having a uniform and sufficient strength and durability at a minimum of cost. On account of the thinness of the section, this can only be accomplished by intelligent and constant attention to securing proper proportions of all the ingredients.

Cement

2. Cement shall conform to the present Standard Specifications and Tests for Portland Cement of the A.R.E.A. and subsequent revisions thereof.

Fine Aggregate

3. Fine aggregate shall consist of sand, stone screenings, or a combination thereof, having clean, hard, strong, durable, uncoated grains, and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances. It shall range in size from fine to coarse, preferably within the following limits:

Passing through a No. 4 sieve	not less than 90 per cent
Passing through a No. 50 sieve	not more than 30 per cent
Weight removed by decantation	not more than 3 per cent

Sand shall be tested for organic impurities as follows: Fill a 12 oz. graduated prescription bottle to the 4½ oz. mark with the fine aggregate to be tested. Add a 3 per cent solution of sodium hydroxide until the volume of the sand and solution, after shaking, amounts to 7 oz. Shake thoroughly and let stand for 24 hours. If the solution resulting from this treatment is darker than straw color the fine aggregate shall not be used unless the concrete made with the materials and in the proportions to be used in the manufacture of concrete posts is shown by tests to be of the required strength.

Coarse Aggregate

4. Coarse aggregate shall consist of crushed stone, gravel, or combinations thereof, having clean, hard, strong, durable, uncoated particles free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic or other deleterious matter. It shall range in size from fine to coarse within the following limits:

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[4] Adopted, Vol. 16, 1915, pp. 440, 1040.

[5] Adopted, Vol. 24, 1923, pp. 126, 1141.

For line posts:

Passing a ½-inch screen............not less than 95 per cent
Passing a No. 4 screen...........not more than 15 per cent
Passing a No. 8 screen...........not more than 5 per cent

For corner and end posts:

Passing a ¾-inch screen............not less than 95 per cent
Passing a No. 4 screen...........not more than 15 per cent
Passing a No. 8 screen...........not more than 5 per cent

Bank Gravel

5. Natural combinations of fine and coarse aggregate, in the form of bank gravel, may be used, providing its particles meet all the requirements in Sections 3 and 4 above, including the colorimetric test, and provided such particles are properly graded from fine to coarse within the following limits:

Passing a ½-inch screen...........not less than 95 per cent
Passing a No. 4 screen......from 40 per cent to 70 per cent
Passing a No. 50 screen...........not more than 15 per cent
Weight removed by decantation..not more than 1½ per cent

Water

6. Water for concrete shall be clean and free from oil, or injurious amounts of acid, alkali, organic or other deleterious substance.

Metal Reinforcement

7. Steel reinforcement shall be steel of hard grade and shall conform to the present Standard Specifications for Steel Reinforcement of the A.R.E.A. or, if wire is used, to the present Tentative Specifications for Cold-Drawn Steel Wire of the A.S.T.M., or to such modifications of either of such specifications as may hereafter be adopted by the A.R.E.A. Reinforcement shall be in the form of round or square bars, preferably deformed, or steel wires. Crimped, stranded or flat reinforcing shall not be used. Reinforcing, before being placed in the molds, shall be thoroughly cleaned of mill and rust scale, and of coatings that will destroy or reduce the bond.

(II) PROPORTIONING AND MIXING CONCRETE

Proportioning

8. The unit of measure shall be the cubic foot. One bag of Portland cement shall be considered as one cubic foot. Each of the constituent materials shall be measured separately by volume, using a method which will secure the necessary proportions to produce concrete of the specified strength. The water shall be measured by an automatic device that will secure the same quantity in successive batches.

Strength

9. The proportions of cement, water and aggregate shall be such as to produce a concrete having a compressive strength at 28 days of 2500 lb. per square inch. The proportions of fine and coarse aggregate to produce such a concrete shall be determined by making a screen analysis of the

available aggregates and using such a mixture of cement, aggregate and water as will give a dense, workable concrete of the desired strength.

Consistency

10. The quantity of water used in mixing shall be the least amount that will produce a plastic or workable mixture which can be properly compacted in the forms and around the reinforcement. Under no circumstances shall the consistency of the concrete be such as to permit a separation of the coarse aggregate from the mortar in handling. The consistency shall be measured by the slump test as follows:

The newly mixed concrete shall be placed in a truncated cone-shaped metal mold, 12 inches high, 8 inches in diameter at the base, and 4 inches in diameter at the top, and provided with handles at the sides. The concrete shall be lightly tamped with a rod as it is placed in the mold which, when filled, shall be immediately removed and the slump or settlement of the concrete noted.

The maximum slump shall not exceed 5 inches. The consistency shall be checked at the beginning of each daily run and also whenever there is a change in the size or moisture content of any aggregate.

Mixing

11. Mixing shall be done in a batch mixer of approved type, equipped with a suitable charging hopper, water storage, and water measuring device. The entire contents of the drum shall be discharged before recharging. Each batch shall be mixed for not less than 2 minutes after all the materials are in the mixer, during which time the mixer shall rotate at a peripheral speed of about 200 feet per minute. The volume of the mixed batch shall not exceed the manufacturer's rated capacity. The retempering of concrete which has partially hardened shall not be permitted. In cold weather aggregate shall be heated, if necessary, to remove frost and frozen lumps.

(III) DEPOSITING CONCRETE

General

12. Before depositing concrete the molds shall be thoroughly cleaned and coated with non-staining mineral oil or other approved material. The mixer should be so located that the concrete can be discharged directly into the molds or conveyed to the molds in such a manner as to cause no separation of the ingredients. Each mold shall be completely filled in one continuous operation.

Molds

13. Molds shall be substantial, rigid, and true to plan. Metal molds are more satisfactory than wooden molds.

Placing Reinforcing

14. The reinforcing shall be securely and continuously held in its proper position in the post during the placing of the concrete and until the post is removed from the mold. Metal spacers that would cause distinct lines of cleavage in the post shall not be used. The reinforcing shall be

supported as often as is necessary to prevent its sagging to any appreciable extent due to its own weight or to the weight of the wet concrete.

Compacting

15. Concrete shall be thoroughly compacted into the molds and around the reinforcing. This is best accomplished by giving the molds a jogging or vibratory motion during and after depositing.

Finish

16. All posts shall have a clean, smooth finish. If any pockets or holes are discovered upon removal from the molds, they shall be immediately filled with a mixture of one part cement to two parts fine aggregate. Pockets or holes more than ½ inch in depth or more than ½ inch in diameter, or any exposure of the reinforcing shall cause the rejection of the post.

(IV) CURING AND HANDLING POSTS

Curing

17. The posts shall remain in the molds until the concrete has thoroughly hardened and in no event for less than 24 hours after placing. During this time and until they are cured the posts shall be carefully handled and protected from shock. When the posts are removed they shall be stacked in a nearly vertical position and protected from direct sunlight. They shall be kept thoroughly wet for eight or ten days after being made. They shall be cured for not less than 90 days, when cured naturally, before being shipped or set. Posts shall not be cured out of doors during freezing weather.

(V) MISCELLANEOUS

Inspection

18. All materials and all processes of manufacture shall be subject to inspection and approval at all times. Free access shall be provided for all authorized inspectors to all parts of the plant in which the posts or the materials are made, stored or prepared.

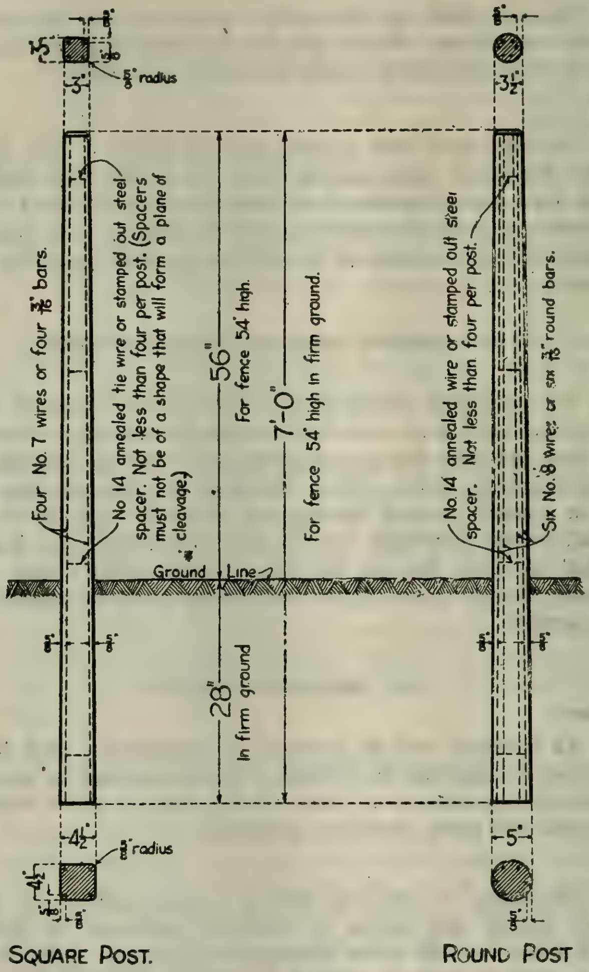
Tests

19. All testing of materials used in the manufacture of posts, all preparing, storing and testing of concrete specimens, as provided in Section 8 hereof, and all screen analyses of aggregates, shall be made in accordance with the methods adopted or approved by the A.R.E.A. and in effect at the time such tests, analyses, etc., are carried out. In case the A.R.E.A. shall not have approved or adopted any methods for such tests, analyses, etc., the same shall be made in accordance with the methods then adopted or approved by the A.S.T.M.

Patents

20. The manufacturer or contractor shall pay all royalties for the use of patented designs or devices or forms of construction and protect the Railway Company from all claims of infringements or liability for the use of such patents.

PLAN OF CONCRETE FENCE POSTS


5/8"
5/8" radius
3"
Four No. 7 wires or four 3/16" bars.
No 14 annealed tie wire or stamped out steel spacer. Not less than four per post. (Spacers must not be of a shape that will form a plane of cleavage.)
56" For fence 54" high.
7'-0" For fence 54" high in firm ground.
Ground Line
28" In firm ground
5/8"
4 1/2"
5/8" radius
SQUARE POST.
5/8"
3 1/2"
No. 14 annealed wire or stamped out steel spacer. Not less than four per post.
Six No. 8 wires or six 3/16" round bars.
5"
ROUND POST

Dimensions of base are for 7' posts. If a longer post is required on account of soft ground or high fence, increase the bottom diameter or length of side, 1/4" per foot of additional length.

Fence wires shall be attached to post by means of Western Union tie, molded holes thru post, loops of galvanized wire projecting from the post, or other suitable device.

In case climatic conditions or unusually heavy service make a stronger post seem advisable this increased strength is more economically secured by increasing the size of the reinforcing rather than the size of the post.

December, 1922.

[6]SURFACE STOCK-GUARDS

(1) A stock-guard should be so constructed as to avoid projecting surfaces liable to be caught by loose or dragging portions of equipment.

(2) It should be effective against all live-stock, have no parts which would catch or hold animals or unnecessarily endanger employees who pass over it in the discharge of their duties.

(3) It should be reasonable in first cost, durable and easily applied and removed, so as to permit repairs to track at minimum expense.

(4) It should not rattle during passage of trains.

[7]SNOW FENCES, SNOW SHEDS AND RECOMMENDED METHODS OF SNOW REMOVAL

(1) Snow is carried by the wind close to the surface of the ground and is deposited in railway cuts on account of the eddies which they cause in the wind. The function of the snow fence is to form artificial eddies on the windward side of the cut at sufficient distance to cause the snow to deposit between the snow fence and the cut.

(2) The location of the drift or eddy depends upon the form of the fence. A tight fence of sufficient height causes the snow to accumulate on the windward side of the fence; an open fence causes the snow to accumulate principally on the leeward side. The distance between the drift and the fence depends upon the height of the fence, the width of the openings between the boards, the velocity of the wind and the character of the snow.

(3) The character of a snow fence and its location for the protection of a given point depends largely upon local conditions, some of which can only be determined by experiment, and for this purpose portable snow fences are recommended.

(4) Where local conditions permit, a permanent snow fence located on the right-of-way is most economical.

(5) Where permanent wood fences are used, the boards should be laid close, where the right-of-way is 50 feet or less from the center of the track; for greater distances, space should be provided between the boards and at a distance of 100 feet, 50 per cent of the fence should be open space.

(6) The height of permanent board fences depends upon the probable amount of snow. The maximum height, however, should not exceed ten feet.

(7) In most cases local conditions require the use of a portable snow fence. These fences are usually erected in the fields adjoining the right-of-way. They should be set on the windward side of the track at right angles to the prevailing winds; to provide for variations in the direction of the

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[6] Adopted, Vol. 5, 1904, pp. 387, 390, 459, 461, 462; Vol. 11, Part 2, 1910, pp. 1231, 1246; Vol. 16, 1915, pp. 443, 1041.

[7] Adopted, Vol. 10, Part 2, 1909, pp. 877, 881-887, 915-917; Vol. 11, Part 2, 1910, pp. 1239-1241, 1246; Vol. 16, 1915, pp. 441, 1040.

wind, it is sometimes necessary to set the panels in crescent form. For ordinary conditions one line of fence is sufficient. The quantity of snow sometimes, however, requires the use of three or four lines of portable snow fences set parallel and spaced about 100 feet apart. These fences should be removed in the spring so as not to interfere with farming operations.

(8) Hedge fences may be used where the quantity of snow is not too great, and where local conditions, including the economic feature, permit. Properly maintained hedge fences are effective in beautifying the right-of-way.

(9) Stone walls may be used for snow fences where suitable stones for dry masonry walls are available.

(10) Temporary snow fences may be constructed of ties, laid in the form of worm fences.

(11) Railway companies in northern countries should widen their cuts or provide a slope of 4 to 1 on both sides of the cut for all cuts less than four feet deep.

(12) In the construction of new railways or on grade revision, or trestle filling on existing railways in snow districts, the material should be taken from the side of the cuts. A steam shovel cut on each side is most effective in providing a place for snow to accumulate for ordinary snow conditions, for cuts up to 20 feet in depth.

(13) Salt should be used on switches only during that portion of the winter when the snow melts in daytime and freezes at night.

(14) Where exhaust steam is available, it should be carried about 12 inches below the surface of the ground at points where the accumulation of the ice requires frequent removal during the winter.

SNOW PLOWS

(1) Rotary snow plows are necessary for quick removal of snow where the depth of the drift exceeds 6 feet and its length exceeds 300 feet or where the natural snow fall has filled deep cuts which cannot be removed by the push plow. Rotary snow plows are sometimes used to advantage in the removal of snow slides in mountain districts.

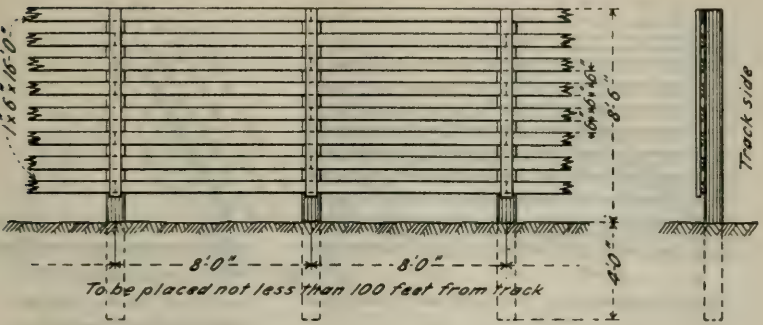
(2) Push plows should be used for a level fall of snow and minor drifts, whenever the depth is too great to be removed by snow flangers. Snow flangers should be used for the removal of snow where the depth is less than 6 inches over the top of the rail.

SNOW SHEDS

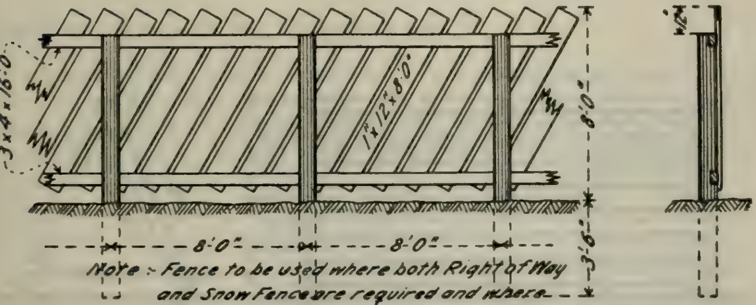
(1) Snow sheds are expensive to construct and maintain, and the railway should be so located, if possible, as to make their construction unnecessary. Their use should be confined to localities which require protection from mountain snow slides, and they should be constructed of permanent material.

PERMANENT SNOW FENCE

Open Boarding

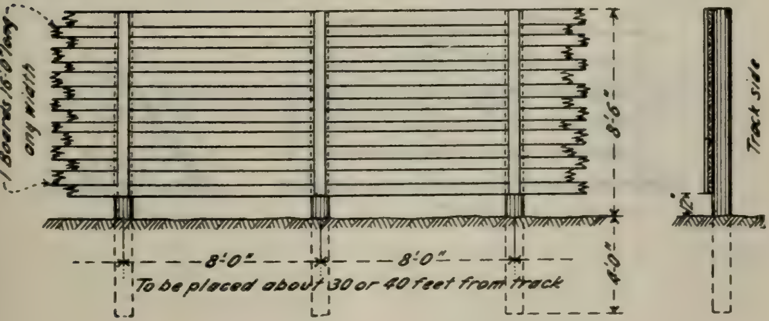


To be placed not less than 100 feet from track



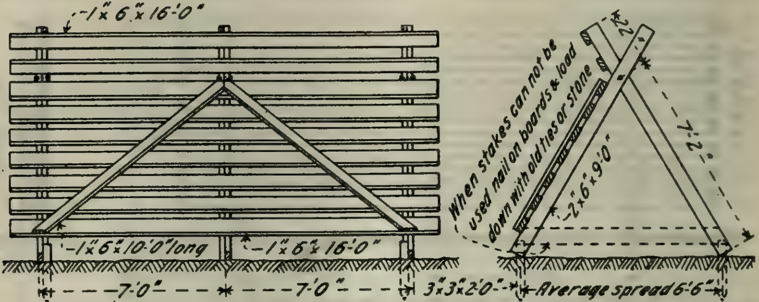
Note :- Fence to be used where both Right of Way and Snow Fence are required and where the Right of Way width is such that the Permanent form will be effective.

Close Boarding



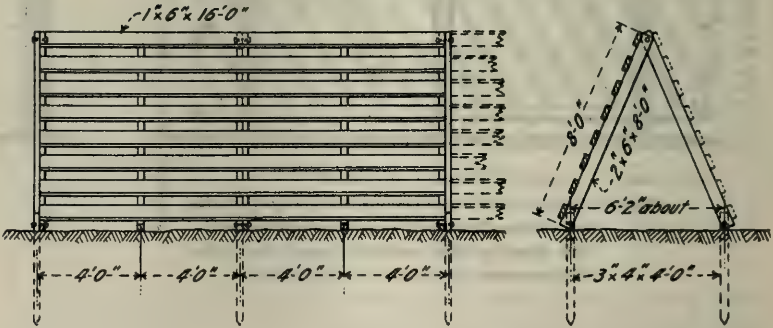
To be placed about 30 or 40 feet from track

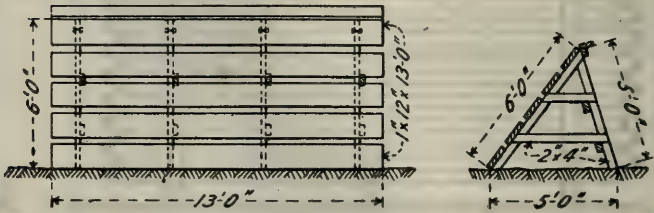
PORTABLE SNOW FENCE



To be placed not less than 100 feet from track

Length of Section may be reduced to 14 ft. when cost per lin. ft is not increased.





[8]SIGNS

Signs in use on railroads may be classified in three groups in accordance with their use:

Signs Governing Train Movements.
Highway Crossing and Trespass Signs.
Roadway Information Signs.

For Signs Governing Train Movements, see Manual, Signal Section, A.R.A.

For Highway Crossing Signs, see under "Grade Crossings."

Roadway Information and Trespass Signs

Trespass Signs, Bridge Signs, Sub-Division and Section Signs, Valuation Section Signs, Mile Posts, Property Line Posts, Curve Elevation Posts, suitable for use under average conditions, are illustrated. Signs such as Dump Ashes, Blind Siding, Water Station, Fuel Station, Beginning of Double Track, End of Double Track, End of Block, Lack of Clearance, Corporation or Sub-Division, and Passing Siding Signs, may be similar to Trespass Signs with appropriate wording.

Plates carrying wording should be made of cast iron or steel plates. In general cast iron plates should be used with the more permanent signs, such as Trespass or Valuation Section. The length of the plate may be increased where necessary to accommodate the wording.

Two and one-half inch wrought iron pipe or good second-hand boiler tubes filled with grout make suitable posts. Where concrete or stone foundations are not used, the post should be set 3 feet 6 inches deep in the ground, and a three-quarter or one-inch pipe 18 inches long run through the pipe post about one foot below the ground line to prevent its being turned around or pulled up.

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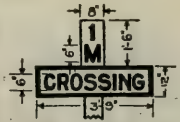
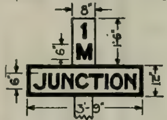
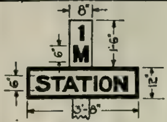
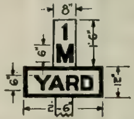
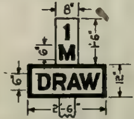
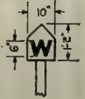
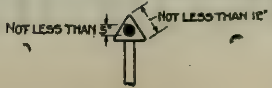
[8] Adopted, Vol. 15, 1914, pp. 872, 881, 1148; Vol. 22, 1921, pp. 268, 276, 997, 999; Vol. 27, 1926, pp. 395, 1318; Vol. 28, 1927, pp. 1295, 1297; Vol. 30, 1929, pp. 490. 1416.

[9]LOCATION OF SIGNS

Signs Primarily for the Information of Trainmen

Name or Purpose of Sign	Sketch of Sign.	Distance at right angles from center line of track to nearest face or edge of Sign.	Distance along track from Sign to object, or condition which it describes or designates.
Railroad Crossing— Distant (one mile) Close (400 ft. more or less)		10′—4″ 10′—4″	One mile. 400′ more or less.
Junction —(One mile)		10′—4″	One mile.
Station—(One mile)		10′—4″	One mile.
Yard—(One mile)		10′—4″	One mile.
Drawbridge— Distant—(One mile) Close (400 ft. more or less)		10′—4″ 10′—4″	One mile. 400′ more or less.
Whistle Post— Highway Station		10′—4″ 10′—4″	1320 ft. 1320 ft.
Flanger Sign		10′—4:	60 ft.

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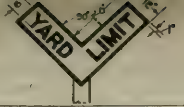
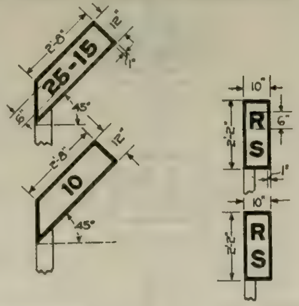
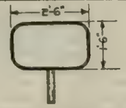
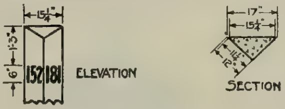
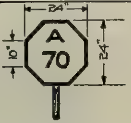
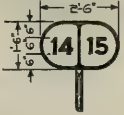
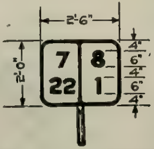
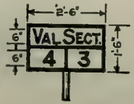
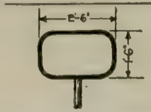
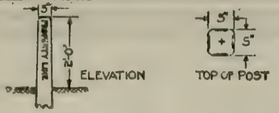
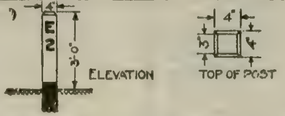
[9] Adopted, Vol. 23, 1922, pp. 450. 1110.

Yard Limit..........................		10′—4″	Governed by operating condition.
Speed Limit—Permanent—Limit....... Slow........ Resume..... Temporary—Limit....... Slow........ Resume.....	 25-15 2′-6″ 12″ 1″ 6″ 45° 10 2′-6″ 12″ 45° R S 10″ 6″ 2′-2″ 1″ R S 10″ 2′-2″	10′—4″ 10′—4″ 10′—4″ 10′—4″ 10′—4″ 10′—4″	3000 ft. 50 ft. 150 ft. beyond. 3000 ft. 50 ft. 150 ft. beyond
Water Station Limit.....................		10′—4″	One mile.
Fuel Station Limit....	"	10′—4″	One mile.
Cinder Station Limit..................	"	10′—4″	At Limits of Dumping.
Beginning and End of Double Track....	"	10′—4″	Opposite Clearance Point.
End of Block.............	"	10′—4″	At Limit of Block.
Blind Siding..........................	"	10′—4″	Opposite Switch.
Passing Siding..........................	"	10′—4″	Opposite Switch.
Lack of Clearance......................	"	**10′—4″**	**At Switch Point.**

Signs for the Information of Passengers and Employees Other Than Trainmen, Though Incidentally Used by Them

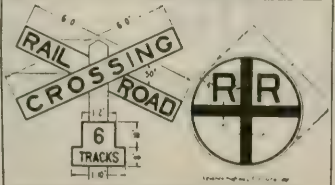
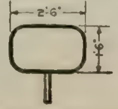
Name or Purpose of Sign.	Sketch of Sign.	Distance from center line of track to nearest face or edge of Sign where the track governs the location and side of track on which located.	Distance from other objective as station or property line to Sign where such object governs the location.
Mile Post.	 15¼" 1'-3" 6" 152 181 ELEVATION 17" 15¼" 14" 12" SECTION	10′—4″ North or east side of track or in direction leading from principal termini.	
Bridge Numbers.		10′—4″ Right angles to track and side most conspicuous to passenger trains.	10′—0″
Section.		Parallel to track near right-of-way line.	
Sub-division and Section.	 2'-6" 2'-0" 7 8 22 1 4" 6" 4" 6" 4"	Parallel to track near right-of-way line.	
Valuation Section.		Parallel to track near right-of-way line.	

General Remarks: ★In accordance with information shown on plans already adopted.

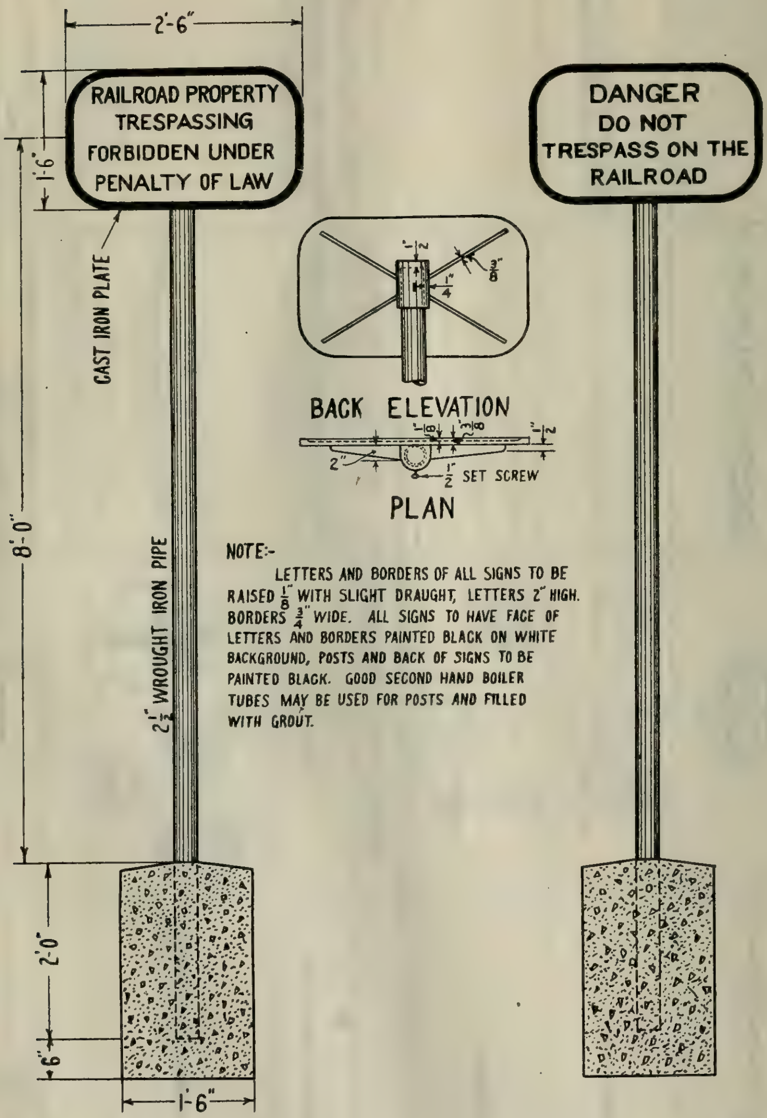
Corporation or Other Political Subdivision		Perpendicular to track near right of way line	
Property Posts	 5" PROPERTY LINE 2'-0" ELEVATION 5" 5" TOP OF POST		All property corners, P. C. and P. T. of curves and 1000 ft. on tangents.
Curve and Elevation		7'—0" from gauge of near rail	

General Remarks: ★In accordance with information shown on plans already adopted.

Signs for the Information of or Warning to the Public

Name or Purpose of Sign	Sketch of Sign	Distance from center line of track to nearest face or edge of Sign where the track governs the location.	Distance from other objective as station or property line to Sign where such object governs the location.
Highway Crossing—At the Crossing Advance warning		17'—0" Advance warning sign to be placed in advance of crossing as required by law or local conditions.	
Trespass—Right-of-way Bridge Crossing		10'—4" or as required by conditions 10'—4" Near right-of-way line	As required by conditions. At end of bridge At point of trespass.

TRESPASS SIGNS

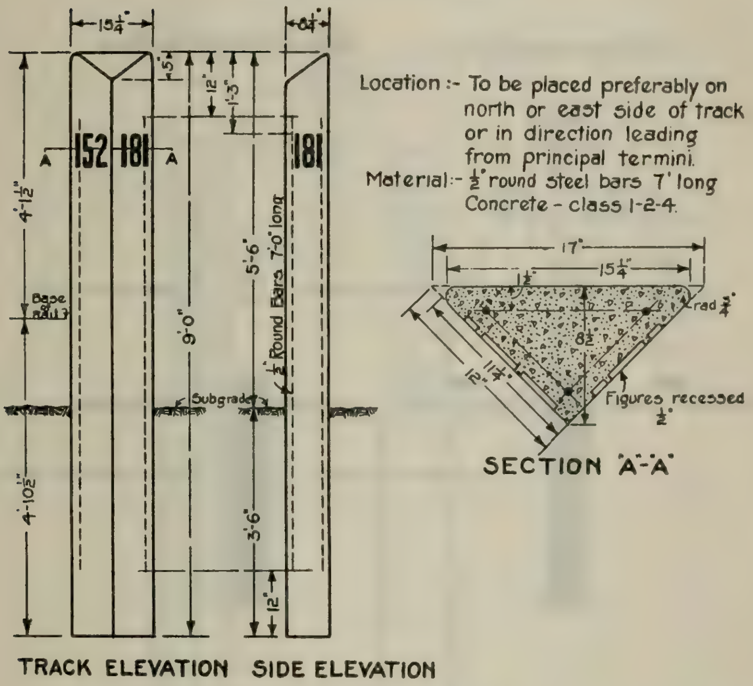


NOTE:-

LETTERS AND BORDERS OF ALL SIGNS TO BE RAISED ⅛" WITH SLIGHT DRAUGHT, LETTERS 2" HIGH. BORDERS ¾" WIDE. ALL SIGNS TO HAVE FACE OF LETTERS AND BORDERS PAINTED BLACK ON WHITE BACKGROUND, POSTS AND BACK OF SIGNS TO BE PAINTED BLACK. GOOD SECOND HAND BOILER TUBES MAY BE USED FOR POSTS AND FILLED WITH GROUT.

Wording on Trespass Sign is suggestive only and should conform to local conditions.

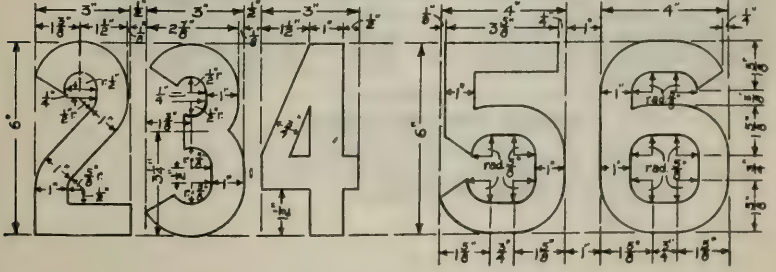
MILE POST



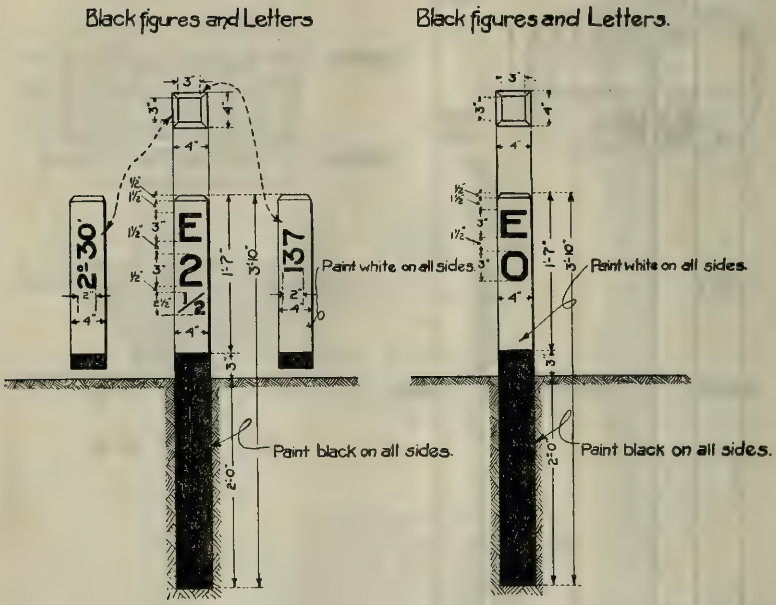
Location :- To be placed preferably on north or east side of track or in direction leading from principal termini.

Material :- ½" round steel bars 7' long
Concrete - class 1-2-4.

TYPICAL DETAIL OF NUMBERS


Sizes to be used when 3 are required.
Sizes to be used when 1 or 2 only are required
3"
3"
3"
1⅜"
1½"
2⅞"
1½"
1"
6"
4"
4"
3⅜"
1"
rad ⅝"
1⅝"
¾"
1⅝"
1"
1⅝"
¾"
1⅝"

ELEVATION POSTS


Black figures and Letters
Black figures and Letters.
3"
4"
E
2
½
2°30'
137
1'-7"
3'-10"
3"
2'-0"
Paint white on all sides.
Paint black on all sides.
E
0
Paint white on all sides.
Paint black on all sides.

FULL ELEVATION POST

SINGLE TRACK

Set on inside of curve at each end 7'-0" from gauge side of near rail to near side of post and opposite "End of Easement" in all cases. Elevation to read approaching curve, Degree of Curve to be on side facing track, and number of Curve to be on side opposite Elevation.

ZERO ELEVATION POST

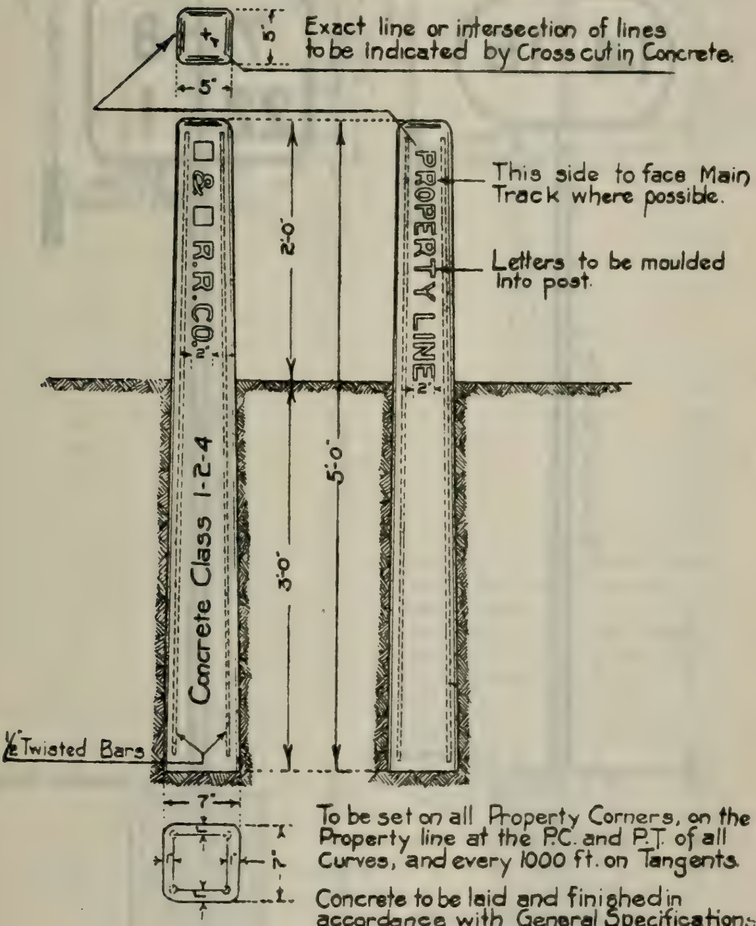
SINGLE TRACK

Set on inside of curve at each end 7-0 from gauge side of near rail to near side of post and opposite Beginning of Easement, or where no Spiral is used at the point of run-off on tangents. Figures to read approaching Curve.

DOUBLE OR FOUR TRACK

Above notes apply also to Double or Four Track except, that all posts must be set on outside of Tracks.

PROPERTY LINE POST



Exact line or intersection of lines to be indicated by Cross cut in Concrete.

This side to face Main Track where possible.

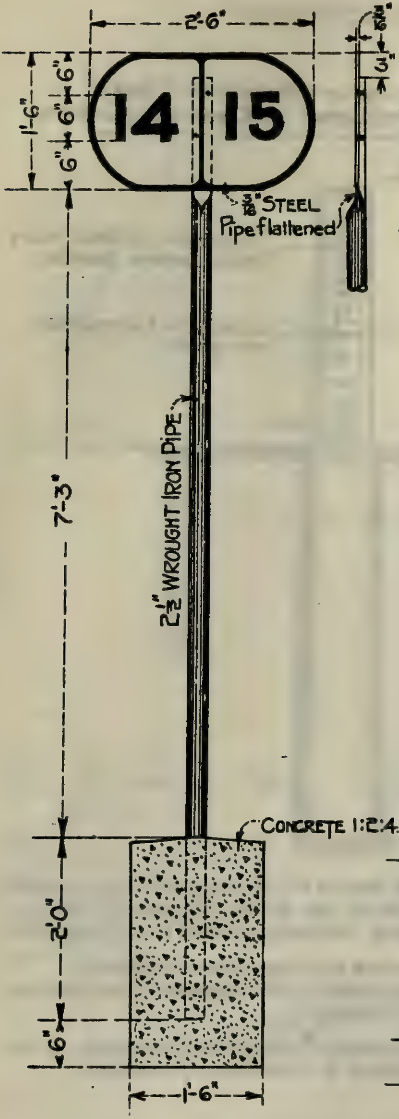
Letters to be moulded into post.

To be set on all Property Corners, on the Property line at the P.C. and P.T. of all Curves, and every 1000 ft. on Tangents.

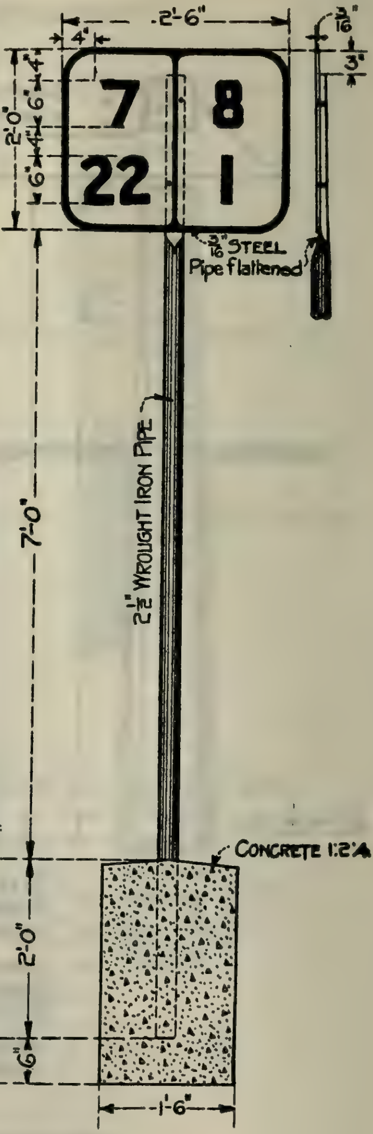
Concrete to be laid and finished in accordance with General Specifications for masonry.

All exposed edges of Concrete to be rounded to a radius of One inch.

SECTION POST

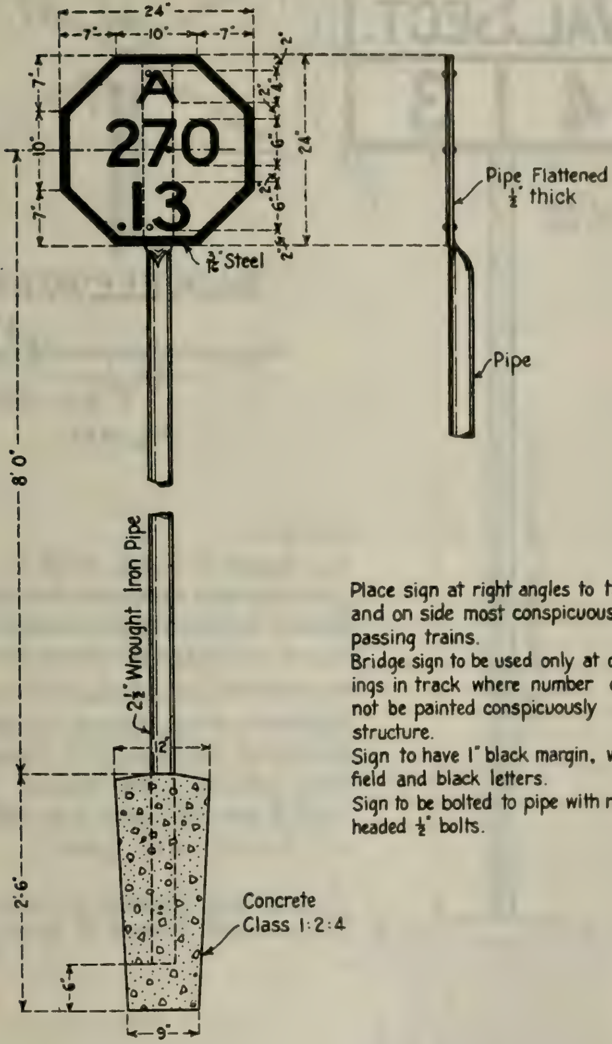


SUB-DIVISION POST



SIGNS TO HAVE 1" BLACK MARGIN, WHITE FIELD AND BLACK LETTERS. PLACE SIGN PARALLEL TO TRACK NEAR RIGHT OF WAY LINE.

BRIDGE SIGN



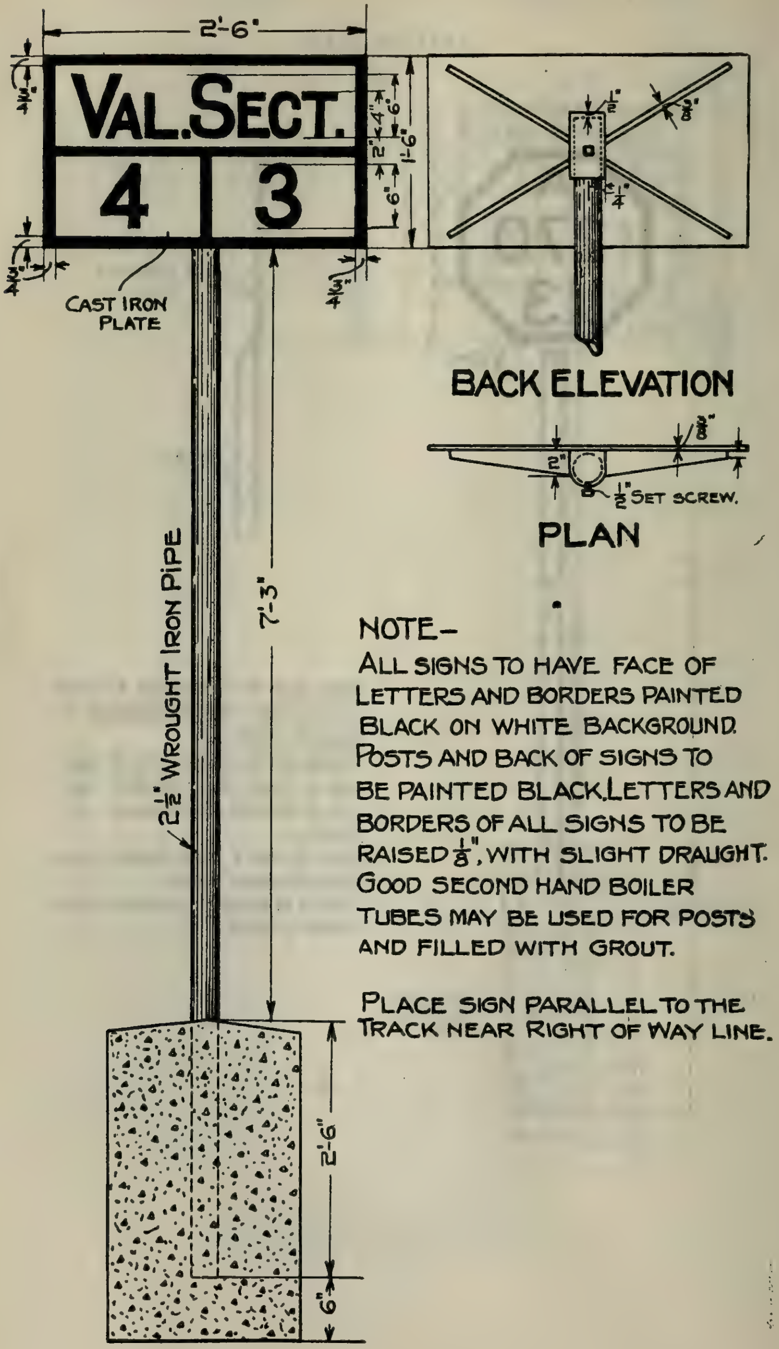
Place sign at right angles to track and on side most conspicuous to passing trains.

Bridge sign to be used only at openings in track where number can not be painted conspicuously on structure.

Sign to have 1" black margin, white field and black letters.

Sign to be bolted to pipe with round headed ½" bolts.

VALUATION SECTION SIGN



NOTE–
ALL SIGNS TO HAVE FACE OF LETTERS AND BORDERS PAINTED BLACK ON WHITE BACKGROUND. POSTS AND BACK OF SIGNS TO BE PAINTED BLACK. LETTERS AND BORDERS OF ALL SIGNS TO BE RAISED ⅛", WITH SLIGHT DRAUGHT. GOOD SECOND HAND BOILER TUBES MAY BE USED FOR POSTS AND FILLED WITH GROUT.

PLACE SIGN PARALLEL TO THE TRACK NEAR RIGHT OF WAY LINE.

[10]SPECIFICATIONS FOR THE CONSTRUCTION OF BITUMINOUS CROSSINGS

General

1. These specifications cover the use of emulsified asphalt, rock asphalt and cut-back products in the construction of bituminous crossings. They must be carried out in detail and with good workmanship.

Foundation

2. All the old ballast shall be removed for the full width of the crossing between lines not less than two feet outside each rail and replaced with new ballast consisting of clean crushed stone or clean gravel preferably washed, having a depth of not less than 6 inches below the bottom of the tie.

Provision shall be made for draining the roadbed. All ties not in good condition shall be removed and replaced with new ties (preferably treated ties) fitted with tie plates. All badly worn track material shall be replaced, eliminating rail joints if practicable.

The track shall be carefully lined and surfaced.

The new ballast shall be thoroughly tamped to form an unyielding foundation, the surface of which shall be four inches below top of rail for a crossing where an emulsified material is used; 3 inches where a cut-back material is used, and one and one-half inches where rock asphalt is used. Where the crossing is to be constructed of rock asphalt the voids in the stone ballast above top of tie shall be filled with fine stone and tamped to form a solid pavement.

The foundation shall be dry when rock asphalt is applied.

The new ballast shall conform to the American Railway Engineering Association Specifications for Ballast.

Handling Materials

3. Bitumens shall be thoroughly mixed before removal from the barrel.

Emulsified asphalt shall not be exposed to freezing temperatures.

Cut-back products contain an inflammable solvent and care should be taken to keep them away from open flames.

Concrete in which a cut-back mixture is used shall be made and stored at least five days before using. It shall be left uncovered to permit curing but shall be protected from rain.

Rock asphalt shall not be laid on or spread when the temperature is below fifty degrees Fahr. nor on a damp foundation.

Method of Constructing Pavement

4. (a) When an emulsified asphalt is used as the cementing agent, the following paragraphs shall govern:

Binder Course.—Upon the foundation of ballast there shall be spread evenly a layer of bituminous concrete which, after being thoroughly tamped, shall be two and one-half inches thick with top surface one and one-half inches below top of rail. It shall be made in the following proportions:

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[10] Adopted, Vol. 26, 1925, pp. 578, 1407; Vol. 27, 1926, pp. 404, 1320.

1 cu. ft. clean ballast stone.
⅓ to ½ gal. of bitumen.

The concrete shall be thoroughly mixed and the stone uniformly coated with the bitumen. This can be done by placing the stone on a mixing board in a layer about six inches deep, adding the bitumen, and then raking or turning over the mixture with shovels.

WEARING SURFACE.—Upon the binder course there shall be spread evenly a layer of bituminous concrete which shall be thoroughly tamped, preferably with a self-propelled roller. When such a roller is used, the finished surface, after rolling, shall be level with the top of rail but not crowned. When tamped by hand or with a hand roller, the finished surface shall be from one-half inch to one inch above the top of rail to allow for compacting by vehicles. The concrete shall be made on a mixing board in the same manner as the binder course and in the following proportions:

1 cu. ft. ¾ inch clean stone.
1 gal. of bitumen.

SEAL COAT.—A seal coat of clean sand mixed with bitumen shall be spread over the crossing to fill the voids but not to make a layer. It shall be made in the following proportions:

1 cu. ft. wet sand.
1½ gal. of bitumen.

FLANGEWAYS.—Particular attention shall be given to thoroughly compacting the bituminous concrete adjoining flange guards or rail heads. Where flange guards are not provided and flangeways are cut by trains passing over the crossings, they shall be sealed by applying to the grooves a solution of two parts bitumen and one part water.

Method of Constructing Pavement

4. (b) If a cut-back product is used as the cementing agent the following paragraphs shall govern:

WEARING SURFACE.—Upon the foundation of ballast there shall be spread evenly a layer of bituminous concrete which shall be thoroughly tamped, preferably with a self-propelled roller. When such a roller is used the finished surface, after rolling, shall be not less than three inches thick and level with the top of rail, but not crowned. When tamped by hand or with a hand roller, the finished surface shall be from one-half inch to one inch above the top of rail to allow for compacting by vehicles. The concrete shall be made in the following proportions:

1 cu. ft. ¾ inch clean stone.
⅓ cu. ft. sand.
⅔ gal. bitumen.

The concrete shall be thoroughly mixed and the stone uniformly coated with the bitumen. This can be done by placing the aggregate on a mixing board in a layer about six inches deep, adding the bitumen, and then raking or turning over the mixture with shovels.

SEAL COAT.—A seal coat of one-quarter inch stone, pea gravel, or coarse sand shall be spread or crushed evenly over the crossing but only in sufficient quantity to fill the surface voids. It shall be made in the following proportions:

1½ gal. of bitumen.
1 cu. ft. of aggregate.

FLANGEWAYS.—Particular attention shall be given to thoroughly compacting the bituminous concrete adjoining flange guards or rail heads.

Method of Constructing Pavement

4. (c) If a rock asphalt is used, the following paragraphs shall govern:

WEARING SURFACE.—The rock asphalt shall be shoveled into place on the foundation and raked thoroughly to produce an even surface and even thickness of two and one-quarter inches. After raking, the rock asphalt shall lie until the sun and heat of the air begin to bring an oily appearance to the surface. It shall then be tamped or, preferably, rolled with a self-propelled roller until the entire surface is smooth and free from waves, depressions or honey-combed areas, until all roller or tamping marks disappear, and until the finished surface is level with the top of rail.

FLANGEWAYS.—Particular attention shall be given to thoroughly compacting the rock asphalt adjoining flange guards or rail heads. Flange guards should be placed and securely fastened to the ties before any ballast is spread about the top of the ties.

Rock asphalt should be spread at least 4 inches thick, for a distance of at least 6 inches from the rail before being compacted, so as to withstand the effects of vibration.

Repairs

5. Holes or pockets in the pavement shall be repaired as soon as they appear and a small quantity of material shall be stored properly, near the crossing, for this purpose.

COMMITTEE II

BALLAST

[1]DEFINITIONS

GENERAL

Ballast.—Selected material placed on the roadbed for the purpose of holding the track in line and surface.

Sub-Ballast.—Any material of a superior character, which is spread on the finished sub-grade of the roadbed and below the top-ballast, to provide better drainage, prevent upheaval by frost, and better distribute the load over the roadbed.

Top-Ballast.—Any material of a superior character spread over a sub-ballast to support the track structure, distribute the load to the sub-ballast, and provide good initial drainage.

Foul-Ballast.—Ballast which has lost its porosity through the filling up of the voids by cinders, coal dust, disintegration of the ballast itself, dirt, or other foreign matter.

Dust.—Fine particles of sand, clay, loam, or other earthy matter which will pass through a No. 50 screen.

Shoulder.—That portion of the ballast between the end of the tie and the toe of the ballast slope.

Crib.—That portion of the ballast between two adjacent ties.

Depth.—The distance from the bottom of the tie to the top of the sub-grade.

Spot Board.—A sighting board laid across the rails in advance of a raising gang to govern the amount of raise and insure uniform grade line.

KINDS

Chats.—Tailings from mills in which zinc, lead, silver, and other ores are separated from the rocks in which they occur.

Chert.—An impure flint or hornstone occurring in natural deposits.

Cinders.—The residue from the coal used in locomotives and other furnaces.

Clay (Burnt).—A clay or gumbo which has been burned into material for ballast.

Granite (Disintegrated).—A natural deposit of granite formation, which on removal from its bed by blasting or otherwise, breaks into particles of size suitable for ballast.

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[1] Adopted, Vol. 5, 1904, pp. 486, 495, 498-501; Vol. 6, 1905, pp. 736, 745; Vol. 7, 1906, pp. 83, 84, 88, 100; Vol. 10, Part 1, 1909, pp. 678, 721-727; Vol. 16, 1915, pp. 1005, 1159; Vol. 21, 1920, pp. 426, 1391; Vol. 22, 1921, pp. 78, 957; Vol. 23, 1922, pp. 133, 1046; Vol. 25, 1924, pp. 98, 1219. Vol. 30, 1929, pp. 246, 1357.

Gravel.—(a) Pit Run.—Worn fragments of rock and sand occurring in natural deposits.

(b) Screen.—Worn fragments of rock, occurring in natural deposits, that will pass through a 2½-inch ring and be retained upon a No. 10 screen.

(c) Washed.—A gravel from which foreign matter has been washed and the relative proportions of gravel and sand have been determined.

Gumbo.—A term commonly used for a peculiarly tenacious clay, containing no sand.

Sand.—Any hard, granular, comminuted rock which will pass through a No. 10 screen and be retained on a No. 50 screen.

Slag.—The waste product, in a more or less vitrified form, of furnaces, for the reduction of ore; usuually the product of a blast furnace.

Stone.—Stone broken by artificial means into small fragments of specified sizes.

[2]CHOICE OF BALLAST

Natural ballast materials vary greatly in quality, and the choice must often be determined by availability and expediency under the particular existing circumstances.

Financial considerations may control the choice or there may be only one suitable material readily available.

Crushed stone is a manufactured article, and the process being under control, it is practicable to make the product conform to specifications.

In the choice of ballast where gravel is available, it should receive careful consideration, as it has given excellent results, especially when properly screened, crushed and washed.

[3]COMPARATIVE MERIT OF MATERIAL FOR BALLAST

The following sets forth the relative order of effectiveness of various kinds of ballast:

(1) Stone
  (a) Trap rock.
  (b) Limestone.
  (c) Sandsone.

(2) Washed Gravel

(3) Broken Slag (not granulated).
  (a) Precious metal slag.
  (b) Open-hearth slag.
  (c) Blast furnace slag.

(4) Screen Gravel

(5) Pit Run Gravel
  (a) River or stream gravel.
  (b) Hill gravel (not cementing).
  (c) Hill gravel (cementing).

Page 94, Manual:

Eliminate "Comparative Merit of Material for Ballast" (Vol. 31, p. 765; Bul. 327, p. 8).

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[2] Adopted, Vol. 5, 1904, pp. 494, 495, 513, 514; Vol. 6, 1905, pp. 736, 737; Vol. 16, 1915, pp. 1006, 1159; Vol. 22, 1921, pp. 79, 957.

[3] Adopted, Vol. 13, 1912, pp. 95, 949; Vol. 16, 1915, pp. 1007, 1172; Vol. 22, 1921, pp. 79, 957.

(6) Chats

- (a) Chats from zinc ore, which is coarse.
- (b) Chats from lead ore, which is fine.

(7) Burnt Clay or Gumbo

(8) Cinders

- (a) Hard coal cinders.
- (b) Volcanic cinders.
- (c) Soft coal cinders.

[4]SPECIFICATIONS FOR STONE BALLAST

GENERAL

1. Stone for use in the manufacture of ballast shall break into angular fragments which range with fair uniformity between the maximum and minimum size specified herein; it shall test high in weight, toughness, wear and soundness, but low in cementing qualities.

TESTS

Tests shall be made as follows:

Weight

2. Not less than one-half cubic foot of solid stone accurately measured and dried for not less than twelve hours in dry air at a temperature of between 125 and 140 deg. Fahr. shall be weighed. The weight shall be not less than .. lb. per cubic foot.

Toughness

3. A piece of solid rock from which a cylindrical core perpendicular to the bedding plane of the rock, 0.98 in. by 0.98 in. (25 mm. by 25 mm.), can be cut with a diamond core drill, and the ends ground plane shall, after drying, be held on an anvil, weighing not less than 110.23 lb. (50 kg.) in the Page impact machine, like a miniature pile driver, under a plunger with sphere shaped striking surface of 0.39 in. (1 c.m.) radius, which is struck by a hammer when released weighing 4.4 lb. (2 kg.). The test begins with a 0.39 in. (1 c.m.) fall of the hammer for the first blow, and continues with an increased fall of 1 c.m. for each succeeding blow until the test piece fails, the number of blows and height being the same and representing the toughness of the rock. Rock that shows a toughness of less than .... shall be rejected. (A.S.T.M., D. 3-18.)

Soundness

4. Ten small pieces (total weight about 1000 grams 2 lb.) of the rock shall be immersed in a saturated solution at 70 deg. Fahr. of sodium sulphate (Na_2SO_4) for 20 hours, after which they shall be placed for four hours in a drying oven maintained at 100 deg. C. The treatment shall be repeated five times. Rock which exhibits checking, cracking or disintegration shall be rejected.

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[4]Adopted Vol. 26, 1925, pp. 440, 1311.

Wear

5. Eleven pounds (five kg.) of freshly broken fragments of stone as nearly alike as possible, shall, after thorough drying, be placed in hollow iron abrasion cylinders, 7⅞ in. (20 c.m.), in diameter and 12.4 in. (34 c.m.) in depth, which are revolved at the rate of 30 revolutions per minute for 10,000 revolutions for each test, after which the pieces shall be thoroughly washed, dried and weighed and the percentage of dust or detritus by weight that will pass through a screen with 1/16 in. (1.6 c.m.) mesh shall be considered the percentage of wear. Rock that has a greater percentage of wear than .... for trap rock, and .... for limestone, shall be rejected. (A.S.T.M., D. 2-08.)

Cementing Quality

6. One and one-tenth lb. (one-half kg.) of stone which can be crushed to pea size, shall be placed (dry) in a ball mill which contains two steel shot weighing 20 lb. (9.07 kg.) each, given 5000 revolutions at the rate of thirty (30) revolutions per minute, and the dough resulting from a mixture of the dust screened through a 100 mesh sieve, and water, placed in an air tight vessel for three (3) hours, and then rekneaded, shall be made into six cylindrical briquettes 0.98 in. (25 m.m.) in diameter and 25 m.m. in height formed under a pressure of 1877.5 lb. per sq. in. (132 kg.) after which they shall be allowed to dry 20 hours in air, four hours in a hot air bath at 100 deg. C. (212 deg. Fahr.) and then cooled for twenty minutes in a desiccator, and immediately tested in a machine for ascertaining the crushing strength in pounds per square inch, which is the measure of the cementing value of the rock, the average of five (5) determinations being taken. Rock which has a greater cementing value than .... shall be rejected.

Frequency

7. Tests may be made from time to time at the option of the purchaser, and especially when new strata are being opened up for crushing into ballast.

Selection of Samples

8. Each stratum of a quarry shall be tested separately and not averaged with any other stratum. (A.S.T.M., D. 75-22.)

Averaging

9. For obtaining the values for physical tests, the average results of the numbers of specimens stated in the following table shall be taken:

Kind of Tests	*Weight*	*Percentage of Wear*	*Toughness*	*Cementing Value*	*Soundness*
No. of Tests..............	5	5	5	5	5

Place for Tests

10. Such tests as are deemed necessary shall be made at a testing laboratory selected by the purchaser, but visual inspection and other tests shall be made at the place of manufacture prior to shipments as often as considered necessary.

PRODUCTION REQUIREMENTS

Breaking

11. Stone for ballast shall be broken into fragments which range with fair uniformity between the size which will in any position pass through a two and one-half (2½) inch ring, and the size which will not pass through a three-quarter (¾) inch ring.

Test for Size

12. (Maximum). A sample weighing not less than 150 lb. shall be taken from the ballast as loaded in the cars and placed in or on a screen having round holes two and three-quarter (2¾) inches in diameter. If thorough agitation of the screen fails to pass through the screen ninety-five per cent of the fragments, as determined by weight, the output from the plant shall be rejected until the fault has been corrected.

(Minimum). A sample weighing not less than 150 lb. shall be taken from the ballast as loaded in the cars; weighed carefully and placed in or on a suitable screen having round holes three-quarter (¾) inch in diameter. The screen shall then be agitated until all fragments which will pass through the screen have been eliminated. The fragments retained in the screen shall then be weighed and if the weight is less than 95 per cent of the original weight of the sample, the output of the plant shall be rejected until the fault is corrected.

Handling

13. Broken stone for ballast must be delivered from the screens directly to the cars or to clean bins provided for the storage of the output of the crusher.

Ballast must be loaded into cars which are in good order and tight enough to prevent leakage and waste of material and which are clean and free from sand, dirt, rubbish, or any other substance which would foul or damage the ballast material.

Cleaning

14. The ballast shall be free from dirt, loam, dust or rubbish. When the rock is of such a nature that it does not become clean without preliminary scrubbing, a scrubbing machine shall be provided at the quarry.

Defect Found After Delivery

15. As it is impracticable to inspect all the ballast loaded in cars, carloads of defective material arriving at the site for unloading, and not previously inspected, shall be rejected and returned to the manufacturer, who must pay the freight charges both ways. If unloaded prior to discovery of defectiveness, payment without return of the rejected ballast shall be refused to the manufacturer.

Inspection

16. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer

to satisfy them that the ballast is prepared and loaded in accordance with the specifications and contracts.

In case the inspection develops that the material which has been or is being loaded is not according to specifications, the inspector shall notify the manufacturer to stop further loading and to dispose of all cars under load with defective material.

Measurement

17. Ballast material may be reckoned in cubic yards or by tons, as expedient. Where ballast material is handled in cars, the yardage may be determined by weight, after ascertaining the weight per cubic yard of the particular stone in question by careful measurement and weighing of not less than five cars filled with the material, or the tonnage may be determined for subsequent cars by measurement and converting the yardage into tonnage by the use of the weight per yard as determined above.

Note 1—High quality stone will have the following values:

	Limestone	*Trap*
Weight per cu. ft.	168	175
Toughness	10	15
Wear	5	3
Cementing quality	4 lb.	1 lb.

Note 2—Notation under toughness, wear and selection of samples refers to the Standard Methods of the A.S.T.M.

[5]SPECIFICATIONS FOR WASHED GRAVEL BALLAST

1. Gravel for ballast shall be so prepared that all dust, dirt and loam are removed, that all aggregates that will not in every position pass through a 1½ in. ring are either rejected or crushed and returned to the ballast and that the resultant product conform to the following:

2. Where the percentages of crushed material run between nothing and 20, the ratios of various sizes of aggregates to the whole shall be as follows:

1/10 in. to ¼ in.	min.	25%
	max.	40%
¼ in. to ½ in.	min.	20%
	max.	30%
½ in. to 1 in.	min.	20%
	max.	55%
1 in. to 1½ in.	min.	0%
	max.	35%

3. Where the percentages of crushed material run more than 20 and less than 40, the ratios of various sizes of aggregates to the whole shall be as follows:

1/10 in. to ¼ in.	min.	10%
	max.	30%
¼ in. to ½ in.	min.	20%
	max.	35%
½ in. to 1 in.	min.	20%
	max.	60%
1 in. to 1½ in.	min.	0%
	max.	50%

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[5] Adopted, Vol. 27, 1926, pp. 83, 1279.

4. Where the percentage of crushed material is more than 40, the ratios of the various sizes of aggregates to the whole shall be as follows:

¼ in. to ½ in.	min. 20%	max. 35%
½ in. to 1 in.	min. 25%	max. 60%
1 in. to 1½ in.	min. 5%	max. 55%

Test No. 1. Dust, Dirt or Loam

5. A sample of the prepared ballast containing one-eighth (⅛) cubic foot shall be placed in a watertight receptacle having a capacity of not less than one (1) cu. ft. Into this receptacle shall then be placed two quarts of clear water, after which the receptacle shall be agitated until the gravel is thoroughly washed. The water shall be drained off immediately and placed in a glass jar and allowed to settle. If the sediment deposited in the bottom of the jar is more than one-half of one per cent of the sample, as determined by weight, the output of the plant shall be rejected until the fault has been corrected.

Test No. 2. Large Aggregate

6. A sample weighing not less than 150 lb. shall be placed in or on a screen having round holes 1½ in. in diameter. If a thorough agitation of the screen fails to pass through the screen 98 per cent of the material, as determined by weight, the output of the plant shall be rejected until the fault has been corrected.

Test No. 3. Sand

7. One cubic foot of the prepared ballast shall be thoroughly dried, weighed and placed on a screen having ten meshes to the inch and the screen agitated till all particles which will pass have passed through the screen. If the material which passes through the screen exceeds 3 per cent of the original sample, as determined by weight, the output shall be rejected until the fault has been corrected.

Test No. 4. Proportion of Aggregates in Washed, Crushed and Screened Gravel

8. A sample of the prepared ballast, weighing not less than 150 lb., shall be thoroughly dried, weighed and placed on a screen having holes 1½ in. in diameter; all material which can be passed through this screen shall be placed upon a screen having holes 1 in. in diameter; all material which can be passed through this screen shall be placed upon a screen having holes ½ in. in diameter; all material which can be passed through this screen shall be placed upon a screen having meshes of ¼ in., and all material which can be passed through this screen shall be placed upon a No. 10 screen, and all material which can be, shall be passed through it.

9. If the ratio of the amount of material retained on the 1½ in. screen to the amount of the sample as a whole exceeds two per cent, the product shall be rejected until the fault has been corrected.

10. If the ratio of the amount of the material passing the No. 10 screen to the amount of the sample as a whole exceeds three per cent, the product shall be rejected until the fault has been corrected.

11. If the ratio of the amount of the material retained on each of the screens to the amount of the sample as a whole does not come within the tolerances given above, the material shall be rejected until the fault has been corrected.

Inspection

12. In case inspection develops the fact that the material which has been or is being loaded is not in accordance with these specifications, the inspector shall notify the manufacturer to stop further loading until the fault has been corrected, and to dispose of all defective material that had been loaded in cars, which shall be done at the expense of the Contractor.

Measurements

13. When ballast is being paid for by the ton, and it is impracticable to weigh each car, the weight per yard shall be obtained by weighing at frequent intervals not less than five cars loaded with ballast, the contents of which have been carefully measured. The weight per yard obtained by such a test shall be used in figuring the weight per car until another test is made.

14. When ballast is paid for by the yard, the amount shall be determined by weighing each car, where practicable, and applying the weight per yard as determined by frequent tests. When impracticable to weigh each car, the contents of each car will be carefully estimated by comparison with cars the contents of which have been actually measured.

[6]SPECIFICATIONS FOR PIT RUN GRAVEL BALLAST

For Class A Railways

Bank gravel, which contains more than two (2) per cent dust or forty (40) per cent sand, should be washed or screened.

For Class B Railways

Bank gravel, which contains more than three (3) per cent dust or sixty (60) per cent sand, should be screened or washed. Screened gravel should not contain less than twenty-five (25) per cent nor more than fifty (50) per cent sand.

For Class C Railways

Any material which makes better track than the natural roadbed may be economically used.

METHOD OF TESTING QUALITY OF PIT RUN GRAVEL FOR BALLAST

(1) The size of the sample to be tested should be approximately one cubic foot.

(2) Five average samples of about one cubic foot each should be selected from various parts of the pit which is to be tested. The five samples should then be thoroughly mixed and about one cubic foot of the mixture selected for testing.

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[6] Adopted, Vol. 22, 1921, pp. 81, 957.

(3) To separate the gravel from the sand and dust, use a No. 10 screen, ten (10) meshes to the inch, made of No. 24 wire, B. & S. gage. To separate the sand from the dust, use a No. 50 screen, fifty (50) meshes to the inch, made of No. 31 wire, B. & S. gage.

(4) Measure the percentage of gravel, sand and dust taken from the sample by volume, giving the percentage of each ingredient compared to the volume of the sum of the ingredients, as follows:

$$\text{Per cent of sand} = \frac{S}{G+S+D}$$

Where S = Volume of sand.
G = Volume of gravel.
D = Volume of dust.

(5) When sample is shipped for test it should be carefully and securely marked with name and location of the pit from which it was taken.

SPECIFICATIONS FOR BURNT CLAY BALLAST[7]

Kind of Material

1. Good ballast clay is heavy and plastic, free from sand, gypsum or other impurities. It must not crumble when exposed to air or when brought in contact with heat.

Location

2. The pit should be located on level or moderately sloping ground, not subject to overflow. A water supply is desirable and it should be borne in mind that the sulphurous and carbonaceous gases liberated during the burning period, damage the surrounding vegetation and make habitation in the near vicinity very disagreeable.

Test

3. The location site should be thoroughly tested to determine quality of clay, depth and uniform consistency of deposit, and small quantities should be burned in test kilns to show the quality of ballast to be secured.

Burning

4. Fuel should be fresh, clean slack, and arrangements should be made to secure constant supply. One ton of slack coal is generally sufficient for the perfect burning of four cubic yards of acceptable ballast. From one to one and one-half-inch layer of slack is alternated with from ten to twelve-inch layer of clay, a new layer of slack and clay being applied to the fire every five or six days.

Fires once started must be kept steadily and uniformly burning.

To insure thorough and proper burning of the clay, the top and face of the fire should be frequently raked down to avoid clinker or black spots, caused by too much or too little air.

When fully burnt a proper ballast clay becomes red in color, when the clay contains iron; when under-burnt the clay will show a yellow color.

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[7] Adopted, Vol. 22, 1921, pp. 82, 957.

Size

5. Burnt clay ballast should be crushed or broken, if necessary, so that the largest piece will pass through a 4-inch ring.

Density

6. The finished product should absorb not to exceed 15 per cent of moisture by weight.

[8]CINDER BALLAST

The use of cinder as ballast is recommended for the following conditions: On branch lines with light traffic; on sidings and yard tracks near point of production; as sub-ballast in wet, spongy places; as sub-ballast on new work where embankments are settling, and at places where the track heaves from frost. It is recommended that provision be made for wetting down cinders immediately after being drawn.

A sub-ballast blanket of cinders not less than 12 in. thick is effective in most cases in preventing mud and similar material working up into the top-ballast.

[9]PROPER DEPTH OF BALLAST

(1) On a roadbed material such as clay, loam, etc., subject to deformation by the application of live load, the proper depth of ballast under the tie to produce approximately uniform pressure on the roadbed should be not less than the spacing center to center of the ties. For Class A Track, see Ballast Sections.

(2) On material that approximates the character of good sub-ballast (which will not be deformed by the application of live load), the minimum depth of ballast under the bottom of the tie should be twelve (12) inches.

(3) These depths are required, under the conditions named, to support the track structure; to provide good initial drainage; to reduce upheaval by frost; to serve as a cushion for the track.

(4) A combination of a good sub-ballast 18 to 14 in., and top-ballast 6 to 10 in., making a total of approximately 24 in. under the tie in the aggregate, will produce nearly the same result as though the superior material was used for the full depth.

(5) Until sufficient tests are made under normal traffic conditions, the proper depth of ballast under the tie must rest on opinion, based on experience and supported by such tests as are available, notably the test made by Director Schubert of the German Railways and the "Altoona Test" made by the Pennsylvania Railroad.

(6) Proper drainage of the subgrade is essential to success with any kind of ballast.

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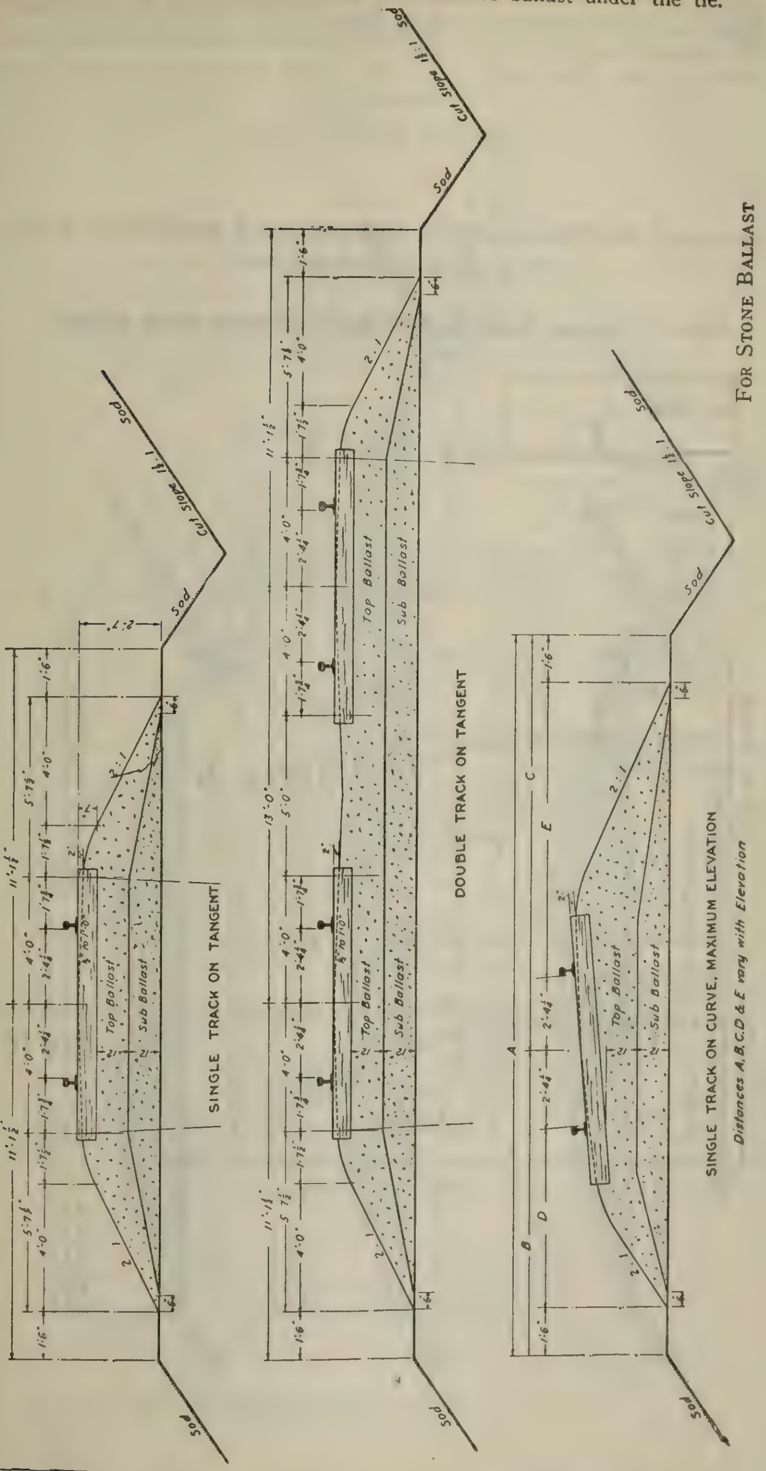
[8] Adopted, Vol. 22, 1921, pp. 80, 957.

[9] Adopted, Vol. 22, 1921, pp. 80, 957. Vol. 30, 1929, pp. 247, 1357.

BALLAST SECTIONS, WITH PARTICULAR REFERENCE TO SUB- AND TOP-BALLAST

Class "A" section should have 24 inches of ballast under the tie.



FOR STONE BALLAST

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[10] Adopted, Vol. 8, 1907, pp. 44-46, 62, 65, 66, 67; Vol. 9, 1908, pp. 309, 311; Vol. 16, 1915, pp. 1011, 1170; Vol. 19, 1918, pp. 712, 1187; Vol. 22, 1921, pp. 86, 957.

BALLAST SECTIONS, WITH PARTICULAR REFERENCE TO SUB- AND TOP-BALLAST

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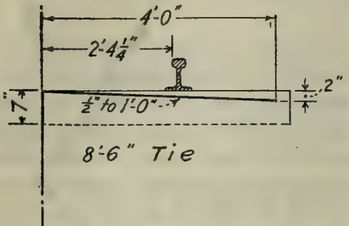


FIG. I

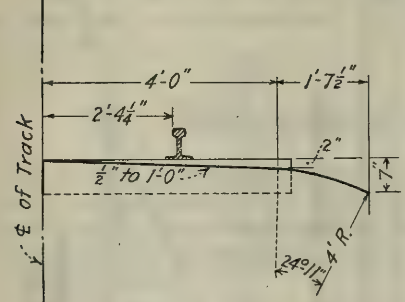


FIG. II

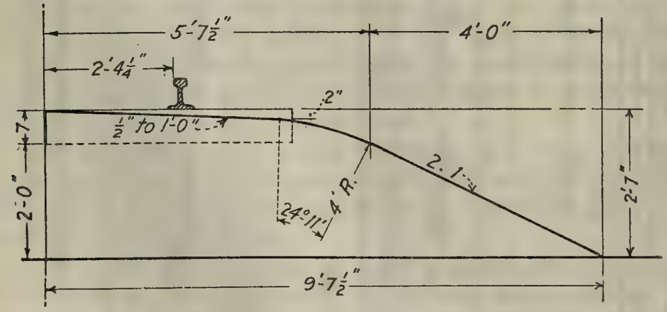
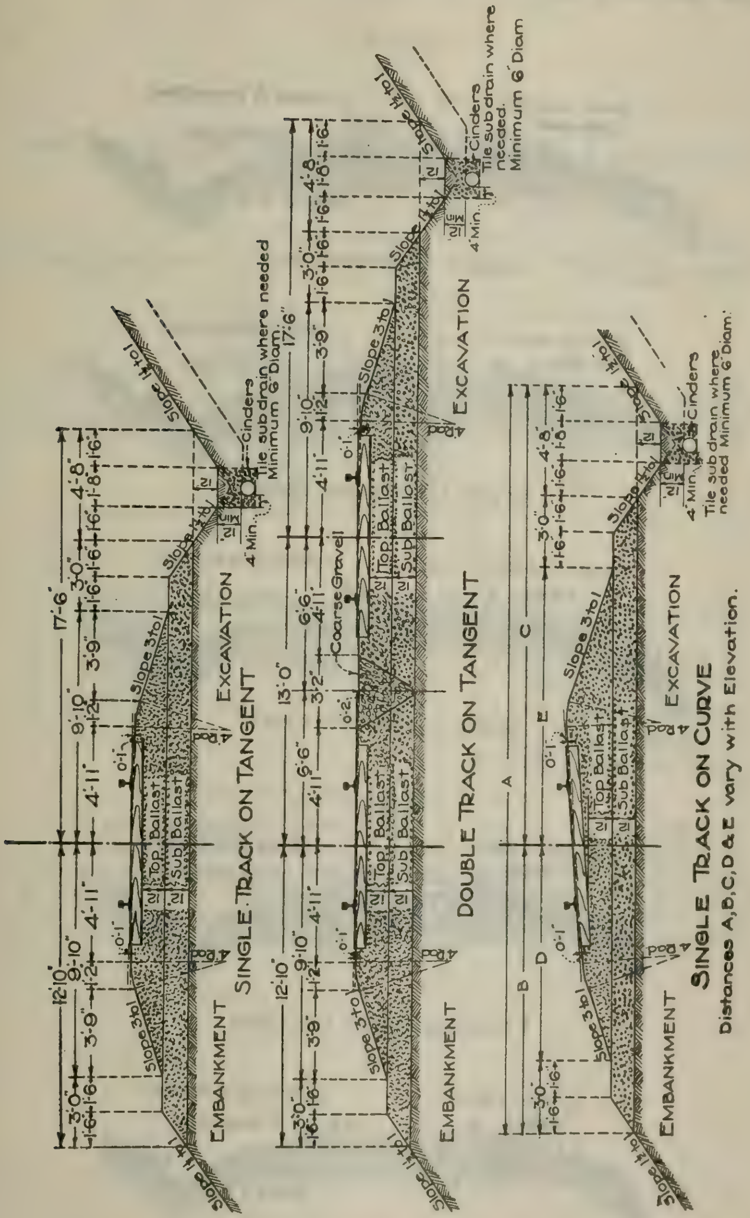


FIG. III

[11]BALLAST SECTION FOR GRAVEL BALLAST ON CLASS A ROADS

Depth of ballast, 24 inches.



SINGLE TRACK ON TANGENT

DOUBLE TRACK ON TANGENT

SINGLE TRACK ON CURVE

Distances A, B, C, D & E vary with Elevation.

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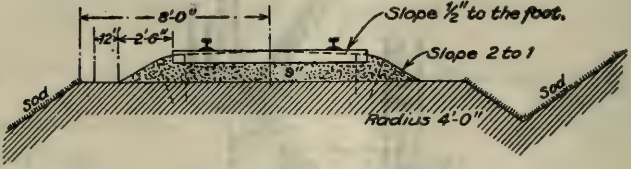
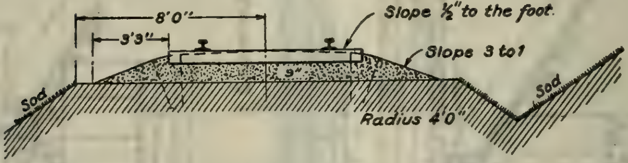
[11] Adopted, Vol. 24, 1923, pp. 118, 1137.

The Sections for Class B track are intended to show minimum depth under ties and are recommended for use only on the firmest, most substantial and well-drained subgrades.

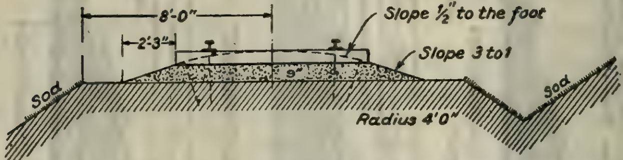
CLASS B.



Crushed Stone and Slag.

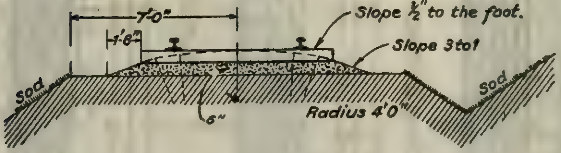


Gravel, Cinders and Chats.

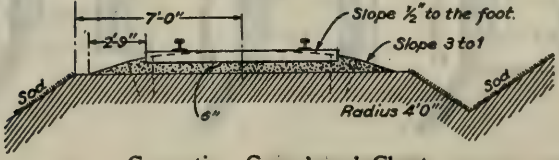


Gravel, Cinders and Chats.

CLASS C.

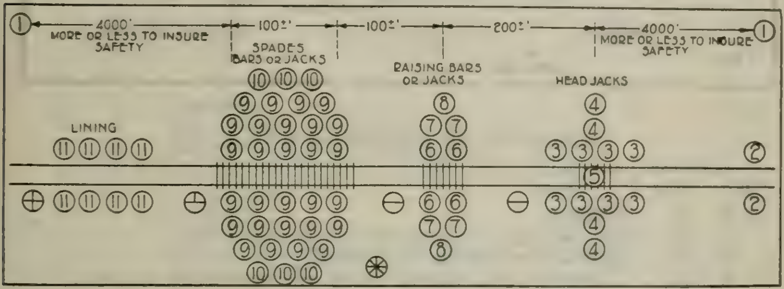


Cementing Gravel and Chert.



Cementing Gravel and Chert.

[12]ORGANIZATION AND DISTRIBUTION OF A BALLAST RAISING FORCE OF 77 MEN



No.	No. of Men	Force	No.	No. of Men	Force
1	2	Flagmen	10	6	Forkers
2	2	Digging Holes for Jacks	11	8	Lining and Filling In
3	8	Head Jacks		1	Water Carrier
4	4	Spaders		1	Tool Man
5	1	Levelman		1	Time and Material Clerk
6	5	Raising Bars or Jacks	⊗	1	Forman Supervising Work
7	4	Tampers	⊖	2	Asst. Foreman Raising Track
8	2	Forkers and Sledges		1	Asst. Foreman Tamping
9	28	Tampers	⊕	1	Asst. Forman Lining Track

Number of Men, 71; Total Force, 77

NOTE.—The diagram presupposes that old track has been skeletonized and that a follow-up gang will do the finished lining and dressing after the track has been pounded down under traffic. The skeletonizing gang should precede the raising gang by about one day's work. Slow order should govern train movements over skeletonized track as well as the track being lifted. Lifting jacks should be set away from the joints, preferably at least two ties. Ties should be respaced if necessary, particularly at the joints.

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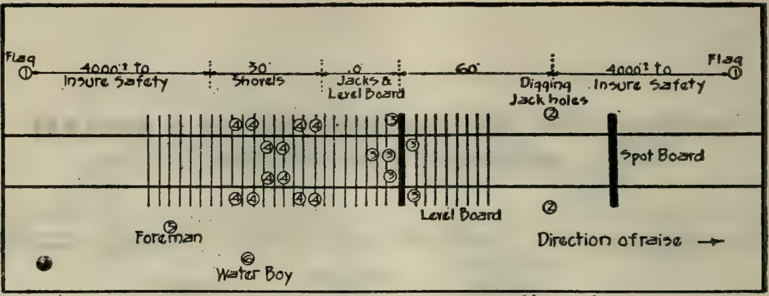
[12] Adopted, Vol. 22, 1921, pp. 85, 957.

[13]ORGANIZATION AND DISTRIBUTION OF A SMALL EMERGENCY BALLAST GANG



GRAVEL OR CINDER BALLAST

No.	*No. of Men*	*Force*
1	2	Flagmen
2	2	Dig jackholes and handle spot board
3	6	Jackmen and handle level board
4	12	Tampers—using shovels inside and outside of rail working in pairs
5	1	Foreman
6	1	Waterboy
		No. of men, 20
		Total force, 24.

TIME STUDY

Schedule: Final raise of four to six inches when completely renewing ballast where track is tamped with shovels in gravel or cinder.

Operation No.	*Operation*	*Time Distribution Minutes per Foot of One Track Gravel or Cinder*
1	Running spot board	0.07
2	Digging jackholes	0.35
3	Jacking up track	0.80
4	Running level board	0.18
5	Tamping	2.80
	Waterboy	0.23
	Two flagmen	0.50
	Foreman (assume gang of twenty men)	0.25
	Total minutes for one foot of one track	5.18
	Standard schedule, hours per foot of one track	.086
	Progress, 257 ft. per hour, allowing 10 per cent detention account of trains.	

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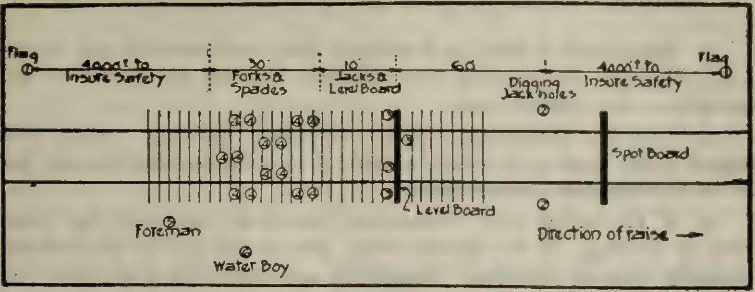
[13]Adopted, Vol. 23, 1922, pp. 133, 1046.



STONE BALLAST

No.	*No. of Men*	*Force*
1	2	Flagmen
2	2	Dig jackholes and handle spot board
3	4	Jackmen and handle level board
4	14	Tampers—using forks inside and outside of rail working in pairs
5	1	Foreman
6	1	Waterboy
		No. of men, 20.
		Total force, 24.

TIME STUDY

Schedule: Final raise of four to six inches when completely renewing ballast where track is tamped with forks in stone.

Operation No.	*Operation*	*Time Distribution Minutes per Foot of One Track Stone*
1	Running spot board	0.07
2	Digging jackholes	0.71
3	Jacking up track	0.85
4	Running level board	0.20
5	Tamping	4.10
	Waterboy	0.30
	Two flagmen	0.60
	Foreman (assume gang of twenty men)	0.30
	Total minutes for one foot of one track	7.13
	Standard schedule hours per foot of one track	.119

Progress, 180 ft. per hour, allowing 10 per cent detention account of trains.

[14]USE AND LIMITATION OF MECHANICAL TOOLS

1. Mechanical devices used to save labor and expense and to expedite the work fall naturally into sequence from the pit, quarry or ballast pile to the finished track.

2. Cars for transporting ballast should be carefully chosen with regard to the work to be done—whether it is to be on track already laid or for an additional parallel track.

3. If for raising track, hopper cars should be used with the ballast plow or tie drag. If for parallel track, side dumps are to be preferred, especially when air operated. Convertible cars where the sides swing out and up, when used with the side plow and unloading engine-drum and cable, are fairly satisfactory when dump cars are not available, which is usually the case when stone ballast is furnished from a private quarry.

4. Anchoring the train and pulling the plow through the train by cable from the locomotive is a poor substitute for the unloading engine. It does beat unloading by hand.

5. The spreader car, especially when air operated, is effective and should be in general use. With this car, ballast for new second track work previously dumped alongside the running track from side dump cars or unloaded by side plows, can be spread out to a grade 2 inches below the bottom of tie and to the outside shoulder to a speed of eight miles per hour. When not in use on ballast work the spreader can be used on a grading dump, and in wet clay or rock, will do the work of fifty men and remain idle most of the time at that.

6. The mechanical tamper has passed the stage where its usefulness under favorable circumstances needs further defense.

7. Around terminals and yards where there is a large amount of frog and switch work, there is no disposition to question the expediency of its use based on its merits alone, entirely apart from any question of scarcity of labor.

[15]USE OF MECHANICAL TAMPERS

Where the track is being lifted from one to three inches, out of face, and on stone:

(1) For use as an individual section tool, use a two-tool pneumatic or a two-tool electric tamper; the former with power plant integral with motor car, and the latter of four-tool capacity power plant of the separate type, on skids: the section force necessary to operate consisting of a section foreman and from six to nine men, depending on the type of machine used and the frequency of tie renewals.

(2) For use as an alternate two-section tool, use a four-tool pneumatic or a four-tool electric tamper; the former with power plant integral with motor car, and the latter of the separate type, on skids: the section

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[14] Adopted, Vol. 22, 1921, pp. 83, 957.

[15] Adopted, Vol. 25, 1924, pp. 100, 1220.

force on each section consisting of a section foreman and from six to nine men, of which combined force, depending on the type of machine used, should be used with the tamping machine; when it is used as a four-tool machine, eight to ten men.

(3) For use as a floating individual unit working over several sections, use a four-tool pneumatic or a four-tool electric tamper, both with power plant integral with motor car. The regular force assigned to this outfit to consist of one experienced mechanical tamper foreman and from five to eight men assisted by the regular section force, depending on the type of machine used.

(4) For use in batteries of two or more tamper units working as an extra or floating gang over extensive stretches of track, use four-tool outfits, either pneumatic or electric. Each unit to be manned by a force consisting of from six to nine men, depending on the type of machine used, together with whatever additional force the nature of the work requires.

[16]RULES FOR CARE OF MECHANICAL TAMPING MACHINES

1. Divide the territory upon which the mechanical tampers are to be operated into district upon which there is a sufficient number of tamping machines, section motor cars or other railway gasoline equipment to warrant employing a gasoline engine mechanic, whose duties would be to make a periodical inspection of all such equipment on his district; make light running repairs; supply small parts as needed; and instruct and advise foreman and operators in use of machines; this mechanic to carry a small supply of parts for light repairs, so that there may be no delay in the making of running repairs.

2. Select one or more central points where there are facilities for heavy repairs and general overhauling, which cannot be handled by district gasoline mechanics, to which equipment may be sent for heavy repairs when needed or for general overhauling during seasons when equipment is not in use, establishing at such point or points, if possible, a staff of mechanics belonging to the maintenance of way organization. At such point or points carry a small stock of parts necessary for heavy repairs and overhauling.

3. Have all tamping equipment overhauled during winter months, so that it will be in first-class condition at the beginning of the season's work.

4. It being desirable to provide sufficient work at the heavy repair points to hold the organization intact throughout the year, the overhauling of section motor cars, hand cars and other maintenance equipment should be undertaken during periods when the general overhauling of tamping equipment is not in progress.

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[16] Adopted, Vol. 24, 1923, pp. 114, 1136.

[17]CLEANING FOUL BALLAST

1. Under usual conditions no ballast, except stone or hard slag, should be cleaned.

(2) Ballast should be cleaned when foul enough to prevent proper drainage.

(3) Clean with ballast forks or screens.

(4) Clean shoulder down to subgrade.

(5) Clean crib to bottom of ties.

(6) Clean space between tracks to depth of 6 inches or more below the bottom of ties.

(7) Clean the berm to bottom of ballast, preferably not less than 12 inches below bottom of tie.

(8) Clean cross ditches between ties approximately every rail length or 39 feet. Cross ditches should not be under rail joints.

(9) Return ballast when cleaned and apply sufficient new ballast to produce the standard section.

(10) Tests, fully described in the report of the Committee on Ballast for 1914, indicate stone ballast can be cleaned by the use of screens for approximately one-half cost of cleaning stone ballast with forks. (For diagram showing details of collapsible screens, see 1914 report.)

(11) Stone ballast should be cleaned: In terminals, at intervals of 1 to 3 years. Heavy traffic, at intervals of 3 to 5 years. Light traffic lines, at intervals of 5 to 8 years.

(12) Per cent of new stone ballast to be applied: Fifteen to 25 per cent.

[18]REINFORCEMENT UNDER BALLAST

(1) Concrete slabs placed under the ballast on soft roadbed where traffic is heavy, and at times under other exceptional circumstances, indicate that a considerable degree of success may be expected from their use, and at reasonable expense. (See Vol. 21, pp. 447 to 465.)

[19]STONE AND GRAVEL BALLAST REQUIRED PER MILE OF TRACK

(1) The shrinkage recommended is the percentage which must be added to the yardage as shown by measurements in cars at the pit in order to equal the yardage required to bring the track to the elevation required by the ballast sections which have been adopted as recommended practice. This does not in any sense take into account the settlement which will take place during a considerable period of time under traffic. To bring the track back to its original elevation after such settlement will require an additional amount of ballast. As the finished top of rail

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[17] Adopted, Vol. 22, 1921, pp. 83, 957.

[18] Adopted, Vol. 22, 1921, pp. 84, 957.

[19] Adopted, Vol. 25, 1924, pp. 98, 1219.

elevation is usually fixed, in many locations at least, it was not thought desirable to provide for the lifting of the track above the established elevation in figuring the amount of material required.

(2) In other words, the quantities and shrinkage named provide material enough to bring the track to the required elevation and dress it according to the standard section when it first leaves the hands of the lifting and surfacing gangs. Future requirements to keep the track at the established elevation are not taken into account.

STONE BALLAST

SINGLE TRACK

Sub-Ballast	2,664 cu. yd.
Top-Ballast	3,995 cu. yd.

DOUBLE TRACK

Sub-Ballast	5,206 cu. yd.
Top-Ballast	7,320 cu. yd.

(3) Allow for shrinkage between measurements in car at the pit and quantity required to bring track originally to standard section: for sub-ballast, 8 per cent to 20 per cent; for top-ballast, 12 per cent to 15 per cent.

GRAVEL BALLAST

SINGLE TRACK

Sub-Ballast	4,726 cu. yd.
Top-Ballast	4,144 cu. yd.

DOUBLE TRACK

Sub-Ballast	7,268 cu. yd.
Top-Ballast	7,626 cu. yd.

(4) Allow for shrinkage between measurements in the car and quantity required to bring track originally to standard section for both top and sub-ballast, from 8 per cent to 20 per cent.

[20]BALLASTING BY CONTRACT

The consensus of opinion is strongly against ballasting by contract in normal times and especially so on operated track.

Advocates of ballasting by contract do so largely as an emergency measure because of the greater flexibility of a contractor's organization in changing the rates of pay and so securing labor in times of stress.

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[20] Adopted, Vol. 22, 1921, pp. 84, 957.

COMMITTEE III

TIES

[1]DEFINITIONS

All-Heart Tie.—A tie having no sapwood.

Boxed-Heart Tie.—An "all-heart" tie with the pith of the tree at or near the centers of the ends of the tie. (Known also as "rifle" or "target" tie.)

Composite Ties.—A tie the essential parts of which are composed of two or more materials.

Concrete Tie.—A tie the essential parts of which are composed of concrete, plain or reinforced.

Cull Tie.—A tie which does not conform to the specifications.

Doty Tie.—A tie affected with a fungous disease.

Half-Moon Tie.—A tie hewed or sawed on top and bottom only, but with bottom of markedly greater width than the top. (Known also as "half-round" tie.) Also a tie hewed or sawed on bottom, top, and sides, with the pith of the tree at or near the bottom of the tie, about midway between the two sides. (Known also as "halved" ties.)

Half-Round Tie.—A tie hewed or sawed on top and bottom only, but with the bottom of markedly greater width than the top. (Known also as "half-moon" tie.)

Halved Tie.—A tie hewed or sawed on top, bottom, and sides, with the pith of the tree at or near the bottom of the tie, about midway between the two sides.

Head Block.—A tie or ties of a set used to support the switchpoint operating mechanism.

Heart Tie.—A tie with sapwood no wider than one-fourth the width of the top of the tie between 20 in. and 40 in. from the middle of the tie.

Heart-and-Back Tie.—A tie with the pith of the tree at or near the side of the tie, about midway between the top and the bottom of the tie. (Known also as "wing" tie.)

Intermediate Tie.—Any tie used between joint ties.

Joint Tie.—A tie used under a rail joint.

Pecky Tie.—A tie made from a cypress tree affected with a fungous disease, known locally as peck.

Pole Tie.—A tie made from a tree of such diameter that not more than one tie can be made from a cross-section. (Known also as "round" tie; and may be "rifle" or "target" tie, "slabbed" tie, or "half-round" or "half-moon" tie.)

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[1] Adopted, Vol. 5, 1904, pp. 73, 74, 78, 106-120, 131, 132; Vol. 6, 1905, pp. 766, 767; Vol. 7, 1906, pp. 33, 37, 66; Vol. 11, Part 2, 1910, pp. 863, 901; Vol. 16, 1915, pp. 522, 1089; Vol. 22, 1921, pp. 317, 1003.

Quartered Tie.—A tie hewed or sawed on top, bottom, and sides, with the pith of the tree at or near a corner of the tie.

Rectangular Tie.—A tie hewed or sawed on top, bottom, and sides. (Known also as "pole" tie, "squared" tie, and "squared-pole" tie; and may be "rifle" or "target" tie, "half-moon" or "halved" tie, "heart-and-back" or "wing" tie, "boxed-heart" tie, or "quartered" tie.)

Rifle Tie.—A tie with the pith of the tree or at near the centers of the ends of the tie. (Known also as "target" tie and "boxed-heart" tie; and may be hewed or sawed on two or four longitudinal surfaces.)

Round Tie.—A tie with rounded sides made from a tree of such diameter that not more than one tie can be made from a cross-section. (Known also as "pole" tie; and may be "rifle" or "target" tie or "slabbed" tie.)

Sap Tie.—A tie with sapwood wider than one-fourth the width of the top of the tie between 20 in. and 40 in. from the middle of the tie.

Score Mark.—A mark made by the axe as an aid in hewing.

Slab Tie.—A tie made from the first or outside cut of a log.

Slabbed Tie.—A tie sawed on top and bottom only. (Known also as "pole" tie and "round" tie.)

Split Tie.—A tie riven out of a cross-section, which is generally of sufficient diameter to yield two or more ties.

Squared Tie.—A tie hewed or sawed on top, bottom, and sides. (Known also as "pole" tie, "squared-pole" tie, and "rectangular" tie; and may be "rifle" or "target" tie, "half-moon" or "halved" tie, "heart-and-back" or "wing" tie, "boxed-heart" tie, or "quartered" tie.

Squared-Pole Tie.—A tie hewed or sawed on top, bottom, and sides, made from a tree of such diameter that not more than one tie can be made from a cross-section. (Known also as "squared" tie; and may be "rifle" or "target" tie or "boxed-heart" tie.)

Steel Tie.—A tie the essential parts of which are composed of steel.

Substitute Tie.—Any tie other than a wood tie.

Switch Tie.—A tie of a set used to support a turnout.

Tapped Tie.—A tie made from a tree, the resin or turpentine of which has been extracted before felling.

Target Tie.—A tie with the pith of the tree at or near the centers of the ends of the tie. (Known also as "rifle" tie, and may be hewed or sawed on two or four longitudinal surfaces.)

Treated Tie.—A tie which has been subjected to a process designed to protect it from decay.

Triangular Tie.—A tie with three longitudinal surfaces, the widest of which is the top of the tie.

Wane Tie.—A squared tie showing part of the original surface of the tree on one or more corners.

Wing Tie.—A tie with the pith of the tree at or near the side of the tie, about midway between the top and bottom of the tie. (Known also as "heart-and-back" tie.)

[2]SPECIFICATION FOR CROSS-TIES

MATERIAL

Kinds of Wood[a]

1. Before manufacturing ties, producers shall ascertain which of the following kinds of wood suitable for cross-ties will be accepted:

Ashes
Beech
Birches
Catalpas
Cedars
Cherries
Chestnut
Cypresses
Douglas fir
Elms
Firs (true)
Gums
Hackberries
Hemlocks
Hickories
Larches
Locusts
Maples
Mulberries
Oaks
Pines
Poplars
Redwoods
Sassafras
Spruces
Sycamores
Walnuts

Others will not be accepted unless specially ordered.

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[a] Each railway will specify only the kind or kinds of wood it desires to use.

PHYSICAL REQUIREMENTS

General Quality

2. Except as hereinafter provided, all ties shall be free from any defects that may impair their strength or durability as cross-ties, such as decay, large splits, large shakes, large or numerous holes or knots, grain with slant greater than one in fifteen.

Resistance to Wear

3. When so ordered, ties from needleleaved trees shall be of compact wood throughout the top fourth of the tie, where any inch of any radius from the pith shall have six or more rings of annual growth.

Resistance to Decay

4. Ties for use without preservative treatment shall not have sapwood wider than one-fourth the width of the top between 20 inches and 40 inches from the middle of the tie, and will be designated as "heart" ties. Those with more sapwood will be designated as "sap" ties.

DESIGN

Dimensions[b]

5. Before manufacturing ties, producers shall ascertain which of the following lengths, shapes, or sizes will be accepted, and whether ties are to be hewed or sawed, and in either case whether on the sides as well as on the top and the bottom.

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[b] Each railway will specify only the length or lengths, shape or shapes, and size or sizes it desires to use; but each railway will use the standard designation for whatever size of tie it specifies. For example, a railway desiring 6 inch x 8 inch ties only will designate them as Size 3; a railway desiring 7 inch x 9 inch ties only will designate them as Size 5. A railway shall not, for instance, designate 6 inch x 8 inch ties as Size 1 and 6 inch x 6 inch as Size 2 or 7 inch x 9 inch as Size 1 and 7 inch x 8 inch as Size 2.

[2] Adopted, Vol. 27, 1926, pp. 690, 1387.

6. Except as hereinafter provided, standard-gage railway ties shall be 8 feet, 8 feet 6 inches, or 9 feet long.

7. Except as hereinafter provided, ties shall measure as follows throughout both sections between 20 inches and 40 inches from the middle of the tie:

8.

Size	Sawed or Hewed Top, Bottom and Sides	Sawed or Hewed Top and Bottom
0	5 inches thick by 5 inches wide on top[c]	5 inches thick by 5 inches wide on top
1	6 inches thick by 6 inches wide on top[c]	6 inches thick by 6 inches wide on top
2	6 inches thick by 7 inches wide on top	6 inches thick by 7 inches wide on top
3	6 inches thick by 8 inches wide on top	6 inches thick by 8 inches wide on top 7 inches thick by 7 inches wide on top[d]
4	7 inches thick by 8 inches wide on top	7 inches thick by 8 inches wide on top
5	7 inches thick by 9 inches wide on top	7 inches thick by 9 inches wide on top
6	7 inches thick by 10 inches wide on top	7 inches thick by 10 inches wide on top

[c] None accepted in standard-gage railway ties.

[d] Railways which specify both 6 inch x 8 inch and 7 inch x 7 inch ties manufactured on top and bottom only and which desire to separate the 6 inch from the 7 inch ties will designate the 7 inch x 7 inch as Size 3A.

MANUFACTURE

9. Except as hereinafter provided, all ties shall be straight, well hewed or sawed, cut square at the ends, have bottom and top parallel, and have bark entirely removed.

INSPECTION

Place

10. Ties will be inspected at suitable and convenient places satisfactory to the railway, at points of shipment or at destination. Ties will be inspected at points other than the railway's property whenever in the judgment of the railway there is sufficient number to warrant it; but the shipper shall provide accommodations for the inspector, at the expense of the railway, while away from rail or steamer lines, and transport him from and to a railway station or steamer landing.

Manner

11. Inspectors will make a reasonably close examination of the top, bottom, sides and ends of each tie. Each tie will be judged independently, without regard for the decisions on others in the same lot. Rafted or boomed ties too muddied for ready examination will be rejected. Ties handled by hoists will be turned over as inspected, at the expense of the producer.

Decay

12. The following decay will be allowed: in cedar and in cypress, "pipe or stump rot" and "peck," respectively, up to the limitations as to holes; in chestnut, "bark disease" up to ¼ inch deep. "Blue stain" is not decay and is permissible in any wood.

Holes

13. A large hole, other than one caused by "pipe or stump rot" in cedar, is one more than ½ inch in diameter and 3 inches deep within, or more than one-fourth the width of the surface on which it appears and 3 inches deep outside, the sections of the tie between 20 inches and 40 inches from its middle. A cedar tie with a pipe or stump rot hole more than 1½ inch in diameter and 15 inches deep will be rejected. Numerous holes are any number equaling a large hole in damaging effect. Such holes may be caused in manufacture or otherwise.

Knots

14. A large knot is one whose average diameter exceeds one-fourth the width of the surface on which it appears; but such a knot may be allowed if it occurs outside the sections of the tie between 20 inches and 40 inches from its middle. Numerous knots are any number equaling a large knot in damaging effect.

Shake

15. One which is not more than one-third the width of the tie will be allowed.

Split

16. One which is not over 10 inches long will be allowed, provided a satisfactory anti-splitting device has been properly applied.

Manufacture

17. A tie will be considered straight: (1) when a straight line along the top from the middle of one end to the middle of the other end is entirely within the tie; and (2) when a straight line along a side from the middle of one end to the middle of the other end is everywhere more than 2 inches from the top and the bottom of the tie.

18. A tie is not well hewed or sawed when its surfaces are cut into with scoremarks more than ½ inch deep or when its surfaces are not even.

19. The top and bottom of a tie will be considered parallel if any difference in the thicknesses at the sides or ends does not exceed ½ inch.

Dimensions

20. The lengths, thicknesses and widths specified will be considered met by ties 1 inch shorter, and ¼ inch thinner and narrower than the standard sizes. Ties over 1 inch but not over 2 inches more in thickness than the maximum ordered will be accepted as one size below the largest tie ordered. Those over 2 inches more in thickness; those over 3 inches more in width; or those over 2 inches more in length than the maximum ordered will be rejected. Ties will be sized up by their smaller ends and sized down by their larger ends. The dimensions of the tie will not be averaged.

21. All thicknesses and widths apply to the sections of the tie between 20 inches and 40 inches from the middle of the tie. All determinations of width will be made on the top of the tie, which is the narrower of the horizontal surfaces, or the one with narrower or no heartwood if both horizontal surfaces are of the same width.

DELIVERY

22. Ties delivered on the premises of a railway for inspection shall be stacked not less than 10 feet from the nearest rail of any track at suitable and convenient places; but not at public crossings, nor where they will interfere with the view of trainmen or of people approaching the railway. Standard-gage ties shall be stacked in alternate layers of 2 and 7, the bottom layer to consist of 2 ties kept at least 6 inches above the ground. The next layer shall consist of 7 ties laid crosswise of the first layer. When the ties are rectangular, the two outside ties of the layers of seven and the layers of two shall be laid on their sides. The ties in layers of two shall be laid at the extreme ends of the ties in the layers of seven. No stack may be more than 12 layers high, and there shall be 5 feet between stacks to facilitate inspection. Ties which have stood on their ends on the ground will be rejected.

23. Each stack shall have fastened to it a tag on which is written the owner's name and address, the date when stacked, and the number of ties of each kind of wood in the stack.

24. All ties are at the owner's risk until accepted. All rejected ties shall be removed within one month after inspection.

25. Ties shall be stacked as grouped below. Only the kinds of wood named in a group may be stacked together.

26. CLASS U—TIES WHICH MAY BE USED UNTREATED

Group Ua

"Heart" black locust
"Heart" white oaks
"Heart" black walnut

Group Ub

"Heart" Douglas fir
"Heart" pines
"Heart" larches

Group Uc

"Heart" cedars
"Heart" cypresses
"Heart" redwood

Group Ud

"Heart" catalpas
"Heart" chestnut
"Heart" sassafras
"Heart" red mulberry

27. CLASS T—TIES WHICH SHOULD BE TREATED

Group Ta

Ashes
Hickories
"Sap" black locust
Honey locust
Red oaks
"Sap" white oaks
"Sap" black walnut

Group Tb

"Sap" cedars
"Sap" cypresses
"Sap" Douglas fir
Firs (True)
Hemlocks
"Sap" larches
"Sap" pines
"Sap" redwood
Spruces

Group Tc

Beech
Birches
Cherries
Gums
Hard maples

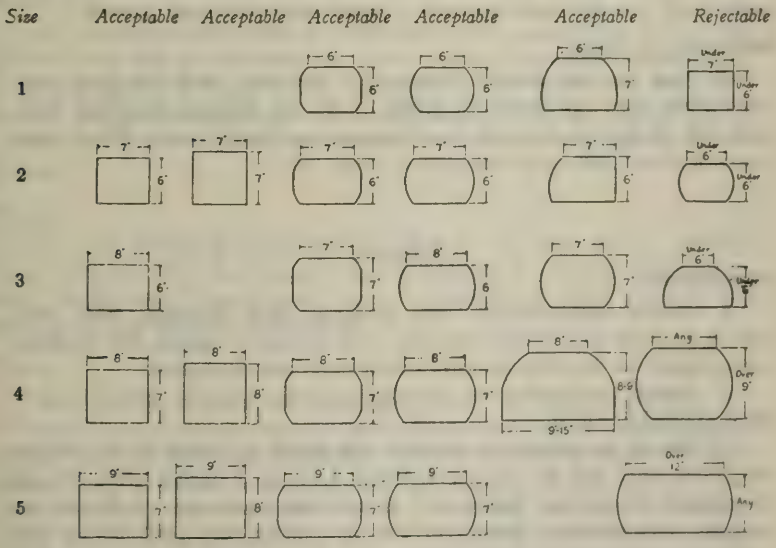
Group Td

"Sap" catalpas
"Sap" chestnut
Elms
Hackberries
Soft maples
"Sap" mulberries
Poplars
"Sap" sassafras
Sycamores
White walnut

SHIPMENT

28. Ties forwarded in cars or vessels shall be separated therein according to the above groups, and also according to the above sizes if inspected before loading, or as may be stipulated in the contract or order for them.

[3]APPLICATION OF THE SPECIFICATION FOR CROSS-TIES



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[3] Adopted, Vol. 30, 1929, pp. 296, 1365.

[4]SPECIFICATION FOR SWITCH-TIES

MATERIAL

Kinds of Wood[a]

1. Before manufacturing ties, producers shall ascertain which of the following kinds of wood suitable for switch-ties will be accepted:

Ashes
Beech
Birches
Cedars
Cherries
Chestnut
Cypresses
Douglas fir
Elms
Firs (true)
Gums
Hemlocks
Larches
Locusts
Maples
Oaks
Pines
Redwood
Spruces
Walnuts

Others will not be accepted unless specially ordered.

PHYSICAL REQUIREMENTS

General Quality

2. Except as hereinafter provided, all ties shall be free from any defects that may impair their strength or durability as switch-ties, such as decay, large splits, large shakes, large or numerous holes or knots, grain with slant greater than one in fifteen.

Resistance to Wear

3. When so ordered, ties from needleleaved trees shall be of compact wood throughout the top fourth of the tie, where any inch of any radius from the pith shall have six or more rings of annual growth.

Resistance to Decay

4. Ties for use without preservative treatment shall not have sapwood wider than one-fourth the width of the top between 12 inches from each end of the tie, and will be designated as "heart" ties. Those with more sapwood will be designated as "sap" ties.

DESIGN

Dimensions[b]

5. Before manufacturing ties, producers shall ascertain what sizes will be accepted and whether ties are to be hewed or sawed, and in either case whether on the sides as well as on the top and the bottom.

6. Except as hereinafter provided, all ties shall be either 6 or 7 inches thick as ordered.

7. Except as hereinafter provided, ties sawed or hewed on top, bottom and sides shall not be less than either 7, 8 or 9 inches wide on top throughout the section between 12 inches from each end of the tie, as ordered; ties sawed or hewed on top and bottom only shall be not less

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[a] Each railway will specify only the kind or kinds of wood it desires to use.

[b] Each railway will specify only the shape or shapes and size or sizes it desires to use.

[4] Adopted, Vol. 27, 1926, pp. 695, 1388.

than either 6 or 7 inches wide on top throughout the section between 12 inches from each end of the tie, as ordered.

8. Each tie shall be of a length specified below:

(Insert complete bill of material here.)

MANUFACTURE

9. Except as hereinafter provided, all ties shall be straight, well hewed or sawed, cut square at the ends, have bottom and top parallel, and have bark entirely removed.

INSPECTION

Place

10. Ties will be inspected at suitable and convenient places satisfactory to the railway, at points of shipment or at destination. Ties will be inspected at points other than the railway's property whenever in the judgment of the railway there is sufficient number to warrant it; but the shipper shall provide accommodations for the inspector, at the expense of the railway, while away from rail or steamer lines and transport him from and to a railway station or steamer landing.

Manner

11. Inspectors will make a reasonably close examination of the top, bottom, sides and ends of each tie. Each tie will be judged independently, without regard for the decisions on others in the same lot. Rafted or boomed ties too muddied for ready examination will be rejected. Ties handled by hoists will be turned over as inspected, at the expense of the producer.

Decay

12. The following decay will be allowed: in cedar and in cypress, "pipe or stump rot" and "peck," respectively, up to the limitations as to holes; in chestnut, "bark disease" up to ¼ inch deep. "Blue stain" is not decay and is permissible in any wood.

Holes

13. A large hole, other than one caused by "pipe or stump rot" in cedar, is one more than ½ inch in diameter and 3 inches deep within, or more than one-fourth the width of the surface on which it appears and 3 inches deep outside, the section of the tie between 12 inches from each end of the tie. A cedar tie with a pipe or stump rot hole more than 1½ inches in diameter and 15 inches deep will be rejected. Numerous holes are any number equaling a large hole in damaging effect. Such holes may be caused in manufacture or otherwise.

Knots

14. A large knot is one whose average diameter exceeds one-fourth the width of the surface on which it appears; but such a knot may be allowed if it occurs outside the section between 12 inches from each end of the tie. Numerous knots are any number equaling a large knot in damaging effect.

Shake

15. One which is not more than one-third the width of the tie will be allowed.

Split

16. One which is not over 10 inches long will be allowed, provided a satisfactory anti-splitting device has been properly applied.

Manufacture

17. A tie will be considered straight: (1) when a straight line along the top from the middle of one end to the middle of the other end is entirely within the tie; and (2) when a straight line along a side from the middle of one end to the middle of the other end is everywhere more than 2 inches from the top and the bottom of the tie.

18. A tie is not well hewed or sawed when its surfaces are cut into with scoremarks more than ½ inch deep or when its surfaces are not even.

19. The top and bottom of a tie will be considered parallel if any difference in the thicknesses at the two sides or ends does not exceed ½ inch.

Dimensions

20. The lengths, thicknesses, and widths specified will be considered met by ties 1 inch shorter and ¼ inch thinner and narrower than the standard sizes. Ties over 1 inch more in thickness, over 3 inches more in width, or over 2 inches more in length than the maximum ordered will be rejected. The dimensions of the tie will not be averaged.

21. All thicknesses and widths apply to the section of the tie between 12 inches from each end of the tie. All determinations of width will be made on the top of the tie, which is the narrower of the horizontal surfaces, or the one with narrower or no heartwood if both horizontal surfaces are of the same width.

DELIVERY

22. Ties delivered on the premises of a railway for inspection shall be stacked not less than 10 feet from the nearest rail of any track at suitable and convenient places; but not at public crossings, nor where they will interfere with the view of trainmen or of people approaching the railway. Ties shall be stacked at least 6 inches above the ground. No tie shall be unsupported for more than 10 feet of its length. Each layer of ties and the ties in each layer shall be not less than one inch apart. Any stacking strips used shall not be over four inches wide. If rectangular ties are used to separate the layers, such

strip ties shall be laid on their sides and the two outside ties as near as possible to the extreme ends of the ties. No ties shall be permitted to overhang more than 2 feet. No stack of ties shall be wider than 10 feet.

23. Each stack shall have fastened to it a tag on which is written the owner's name and address, the date when stacked, and the number of ties of each kind of wood in the stack.

24. All ties are at the owner's risk until accepted. All rejected ties shall be removed within one month after inspection.

25. Ties shall be stacked as grouped below. Only the kinds of wood named in a group may be stacked together.

26. Class U—Ties Which May Be Used Untreated

Group Ua

"Heart" black locust
"Heart" white oaks
"Heart" black walnut

Group Ub

"Heart" Douglas fir
"Heart" pines
"Heart" larches

Group Uc

"Heart" cedars
"Heart" cypresses
"Heart" redwood

Group Ud

"Heart" chestnut

27. Class T—Ties Which Should Be Treated

Group Ta

Ashes
"Sap" black locust
Honey locust
Red oaks
"Sap" white oaks
"Sap" black walnut

Group Tb

"Sap" cedars
"Sap" cypresses
"Sap" Douglas fir
Firs (True)
Hemlocks
"Sap" larches
"Sap" pines
"Sap" redwood
Spruces

Group Tc

Beech
Birches
Cherries
Gums
Hard maples

Group Td

"Sap" chestnut
Elms
Soft maples
White walnut

SHIPMENT

28. Ties forwarded in cars or vessels shall be separated therein according to the above groups, and also according to the above sets or lengths if inspected before loading, or as may be stipulated in the contract or order for them.

[5]SPECIFICATIONS FOR DATING NAILS

MATERIAL

The nails shall be made of iron or steel, galvanized with a coating of zinc (Prime Western, or equal), evenly and uniformly applied, by hot dip process, so that it will adhere firmly to the surface of the iron or steel.

CHEMICAL REQUIREMENTS

The following test shall be made to determine the integrity and adequacy of the zinc coating, and any specimen shall be capable of withstanding this test:

(a) The sample shall be immersed in a standard solution of copper sulphate for one minute and then immediately washed in water thoroughly and wiped dry. This process shall be repeated. If after the fourth immersion there is a copper colored deposit on the sample, or the zinc has been removed, the lot from which the sample was taken shall be rejected.

(b) The standard solution of copper sulphate is prepared by dissolving 36 parts of crystallized copper sulphate in 100 parts of water, then adding enough cupric oxide to neutralize any free acid. The solution is filtered or allowed to settle and decanted, then diluted with water until its specific gravity is 1.186 at 65 deg. Fahr. While nails are being tested, the temperature shall be at no time less than 60 deg. Fahr. nor more than 70 deg. Fahr.

DESIGN

The shank of nail shall be ¼ inch in diameter, and 2½ inches long; the head of nail shall be ⅝ inch in diameter, and 1/16 inch thick, and shall bear two raised figures designating the year, the figures to be ⅜ inch long and raised 1/16 inch.

INSPECTION

(a) Specimens for testing shall be selected by inspector from the finished nails.

(b) As many specimens will be treated as are considered necessary for determining whether or not the requirements of the specifications have been met.

(c) All tests and inspection shall be made at the place of manufacture or sale prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

(d) Inspectors representing the railroad shall have free entry to works of the manufacturer at all times during process of manufacture of nails for purchaser, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the dating nails are in accordance with the specifications.

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[5] Adopted, Vol. 27, 1926, pp. 703, 1388.

1066; Bul. 327, p. 8).
Grading Marks for Ties to Indicate Acceptance (Vol. 31,
p. 1093; Bul. 327, p. 8).
Best Practice for Tie Renewal (Vol. 31, p. 1143; Bul. 327,
p. 9).
Traffic Unit for Use in Comparing Cross-Tie Life (Vol. 31,
p. 1144; Bul. 327, p. 10).

[6]MARKING TIES FOR SERVICE RECORDS

(1) A dating nail should be applied to each tie.

(2) Dating nails should be driven into the tops of the ties, six inches inside the inner flange of the rail and upon the line side of the track.

(3) Dating nails may be applied at the treating plants or after the ties are inserted in track. If the latter, dating nails should be driven the same date tie is inserted.

(4) It is recommended that ties which are passed through boring and adzing machine be branded on end in addition to the boring and adzing. These brands to include, in addition to two figures representing the year, letters or figures, indicating kind of rail for which bored, and letters may be used to indicate kind of wood, or group of woods, and treatment. For example, on one end of the tie "F-90," indicating Fir, bored for 90-lb. rail, and on the other end "A-25," indicating a certain kind of treatment, and the year.

(5) In check sections or in any test ties desired, ties may be marked by copper or zinc tags bearing symbol letters and numbers indicating kind of wood, kind of treatment, and, if desired, individual tie numbers.

[7]CONSERVATION OF TIMBER SUPPLY

(1) The use of treated ties wherever practicable is recommended.

(2) Ties should be protected from failure against mechanical wear by means of tie plates.

(3) Tie specifications should be so drawn and enforced that only such small ties as result from conservative methods of lumbering would be accepted, thus discouraging the cutting of small trees.

(4) Measures should be adopted for reducing forest fires.

(5) Owners should be encouraged to re-forest their lands either by re-planting or natural reproduction.

(6) Proper means should be used to aid in the investigation of tax laws pertaining to forest lands, to obtain legislation which would make it possible to hold growing timber for the purpose of future tie production.

(7) The species of trees to be grown should be selected only after careful and expert study of the available soils and climate.

(8) Plantations should be of such extent as to warrant maintenance appropriations sufficient to insure proper attention.

(9) Experiments with substitute ties should be encouraged.

[8]ECONOMIC COMPARISON OF CROSS-TIES OF DIFFERENT MATERIALS

Except in isolated cases, ultimate economy in labor and material results from the use of properly treated ties, as compared with untreated ties.

The economy of any tie of known price and life may be determined by the following formulas:

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[6] Adopted, Vol. 27, 1926, pp. 702, 1388.

[7] Adopted, Vol. 10, 1909, pp. 490, 493, 494, 521-528; Vol. 11, 1910, pp. 863, 901; Vol. 16, 1915, pp. 522, 1091; Vol. 21, 1920, pp. 579, 1415.

[8] Adopted, Vol. 16, 1915, pp. 524, 1091.

Given:

C = First cost of tie.
C^1 = Amount at compound interest which will produce interest equalling first cost of tie, during life of tie.
R = Rate of interest.
n = Life of tie in years.

Required—Total capitalization of tie:

$$= C + C^1 = \frac{C(1+R)^n}{(1+R)^n - 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Given:

C = First cost of tie.
R = Rate of interest.
I = Interest on first cost.
A = Amount at compound interest which will provide for renewal at end of life of tie.
n = Life of tie in years.

Required—Total annual cost:

$$I = CR$$

$$A = \frac{CR}{(1+R)^n - 1}$$

Total annual cost =

$$I + AR = \frac{CR\,(1+R)^n}{(1+R)^n - 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Given:

R = Rate of interest.
C = Cost of tie of n years life.
C^1 = Cost of tie of n^1 years life.

Tie costs are equivalent when the capitalization or annual costs are equal, or—

$$C^1 = \frac{C\,(1+R)^n}{(1+R)^n - 1} \times \frac{(1+R)^{n^1} - 1}{(1+R)^{n^1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

[9]FUNDAMENTALS TO BE CONSIDERED IN DESIGNS OF SUBSTITUTE TIES

(1) **Safety.**—The substitute must be designed so as to have sufficient strength to prevent failure of the tie or its fastenings, and sufficient bearing surface on the ballast, and with the rail to properly support the loads imposed, and provide against undue deflection in the rail.

(2) **Performance.**—Track will not remain permanently to gage, surface and line under the loads imposed upon it, and labor operations, more or less frequent, will always be necessary to restore it. Therefore, the tie should be designed as far as practicable to resist the forces tending to disturb these conditions and to readily permit restoration.

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[9] Adopted, Vol. 24, 1923, pp. 249, 1148.

FASTENINGS

The fastenings must be of sufficient strength to maintain gage and so designed that without taking the tie from the track and without change to the holes, or fixed bolts or projections in the tie, a reasonable change of width or thickness of the base of rail, or variation of gage, may be made. The fastenings should be such as to offer as little obstruction to derailed wheels as possible. They should permit shimming where necessary, the change of defective rail, or the renewal of rails with ease, and should be replaceable if broken or defective, without disturbing the tie.

GAGE

If the design provides one support under each rail, united by a transverse member to hold gage, the transverse member must be of sufficient strength to maintain gage and plane, and of such design as to withstand a reasonable amount of the damage incident to derailment. The bearing of the rail on the tie must in all cases be of sufficient area to prevent widening of gage by canting.

LINE

The tie should be of such shape that it will not only resist the tendency of track to get out of line, but also permit the track to be thrown back to line. Projections of the base of the tie that project into the ballast make it necessary to lift the track out of surface before relining, and are therefore objectionable. Ties clamped in pairs which enclose a considerable amount of ballast between their several parts, to such extent that the ballast must be removed before the track is lined, add a material burden to the labor necessary to line track.

SURFACE

The tie should have sufficient length and breadth to provide a bearing surface per rail length of track at least equal to that obtained with wood ties, for the same class of track, without reducing the space between the ties to such an extent as to make tamping difficult. It should have sufficient stiffness as a beam to develop the full bearing area on the roadbed.

The base of the tie must be so shaped that the ballast can be readily and effectively tamped under the tie and also not cut into or disturb the tamped bed.

INSULATION

When insulation is desired, the design should permit of insulation without a material change in the tie proper. The fastenings must be so designed that the insulation material will not be subjected to abrasion or to great stress other than compression.

(3) Economy.—The annual cost per unit of length of track for renewals and track maintenance should compare favorably with wood ties. Economy in renewals depends upon first cost and durability. Economy in maintenance will depend upon how closely the requirements heretofore specified are met.

CAUSES OF FAILURE

Past experience indicates that some of the features productive of failure in substitute ties are as follows:

(1) Lack of efficient protection against corrosion.
(2) Failure of rail fastenings.
(3) Failure of insulation.
(4) Loss of beam strength due to weakening tie in vicinity of rail to accommodate rail fastening features.
(5) Use of sharp interior angles or square holes, from which cracks are developed.
(6) Lack of resistance to derailed wheels.
(7) Design of base of tie such as to render tamping difficult or impossible and such as to make maintenance of proper surface of track impracticable.
(8) Design of tie such that track will not hold line, or such as to make lining of track impracticable.
(9) Lack of beam strength causing breakage on yielding roadbed.
(10) Lack of protection in concrete ties from abrasion by ballast.
(11) Lack of provision for expansion and contraction in combination ties of steel and concrete.

[10]CARE OF TIES AFTER DISTRIBUTION

Storing.—Ties should be stacked on ground bare of debris or vegetation for at least two feet around each stack and clear of vegetation over six inches high within ten feet of any stack and sufficiently well-drained so that water will not stand under the stacks or in their immediate vicinity. Decaying wood debris should be thoroughly removed.

Untreated and zinced ties should be stacked so as to obtain free circulation of air, minimum contact, and where storage space is limited maximum economy of space consistent with economical handling, for which purposes the best stacks are one or two by seven to nine, depending on the widths of the ties (Fig. 1, 2 and 3), except when or where the ties would be subject to splitting from too rapid drying, in which seasons or localities semi-solid stacks (7-9x7-9) with the end tiers on their sides (Fig. 4) should be employed. Stacks should not be over 20 layers high, and the bottom layers should be kept at least six inches above the ground. Decayed ties should not be used as sills, nor untreated ties if treated ties or non-decaying materials are available. Alleys at least three feet wide should be maintained between rows of stacks.

Creosoted ties should be stacked as compactly as practicable (Fig. 5 and 6) should be covered with cinders or dirt wherever exposed to falling sparks.

Stored ties of any kind should not be accumulated in groups of stacks without adequate spacing between the groups to permit fire control nor without the maintenance of bared or plowed ground at least three feet wide around the storage yard wherever fire from adjacent areas may spread.

S-Ironing.—Hardwood ties received without anti-splitting devices should have S-irons effectively placed in each end as they are stacked for storage. Any kind of tie which starts to split in track should be S-ironed promptly.

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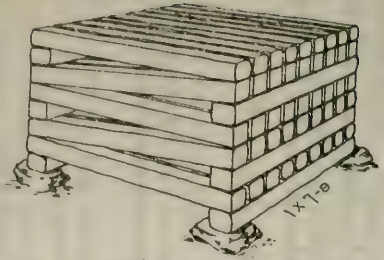
[10] Adopted, Vol. 24, 1923, pp. 251, 1148.

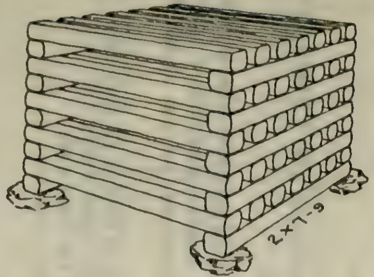
Fig. 1

Fig. 2

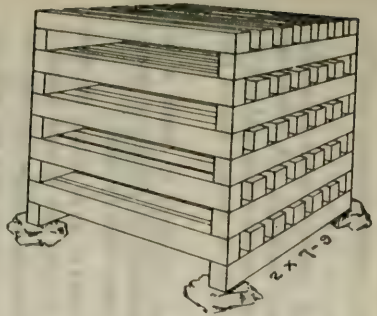
Will Not Dry Too Rapidly
Fig. 3



Round and or Rectangular Ties



Round Ties



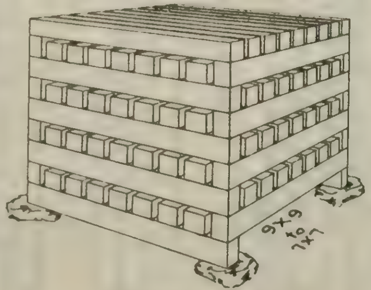
Rectangular Ties

Other Sills Not Necessary if Lowest Two Ties Are Treated

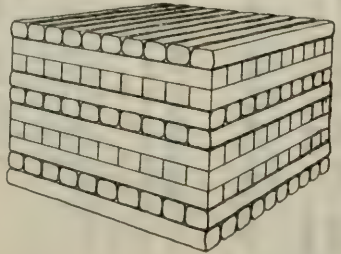
Semi-Solid Stack for Zinced Ties When or Where They May Dry Too Rapidly
Fig. 4

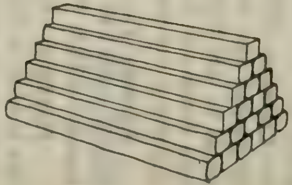
Solid Stacks for Creosoted Ties
Fig. 5

Fig. 6



Rectangular Ties
Other Sills Not Necessary if Lowest Two Ties Are Treated





Round and or Rectangular Ties

Seasoning.—After treatment zinced ties and fir ties which have been boiled should be seasoned at least two months before insertion in track.

Choosing.—Where choice has to be made between distributed ties of unequal age, but equal suitability for given trackage, the oldest ties should be used first, provided it is not practicable to determine and use the least durable tie first and to see that no tie is held in storage longer than one-fifth of its estimated life in track.

Adzing.—Ties should be adzed only when necessary to obtain a full bearing under rail or plate, and as far as practicable all adzing of uneven bearing surfaces should be done by machine rather than by hand.

Handling.—Ties should be moved with tongs so as to reduce the damage incident to handling them; picks, mauls, sledges, and spiking hammers should not be used in moving ties or placing them in position beneath rails.

Installing.—Untreated ties should be placed in track with the wide surface having the most heartwood down; treated ties should be placed in track with the wide surface nearest the pith down, or if the pith is not present in the tie, with the widest surface down.

[11]INSTALLATION AND KEEPING RECORDS OF CROSS-TIE TEST SECTIONS

Test sections shall be so devised that all of the variables affecting life, except the one to be determined, will, as far as possible, neutralize or cancel out. Thus, if the effect of size is to be determined, the test should be somewhat as follows:

1. Select a location where all of the ties of both or all sizes may be put in the *same* track, under the *same* traffic, rail, etc.
2. Use ties of the *same* kind of wood for both sizes.
3. Give both sizes the *same* preservative treatment, or both no treatment.
4. Use *identical* fastenings and plates.

If the effect of traffic is to be determined, a location should be chosen where on *adjacent* tracks light, medium and heavy traffic exists and *at a point where the traffic on each track can be definitely stated in proper traffic units.* Ties of the *same* size, kind of wood and preservative treatment shall be used and the rail, ballast and fastenings and plates shall be *identical* in all cases.

[12]SPECIFICATION FOR TIE PLUGS

Investigation leads to the opinion that the softer woods are preferable for use as tie plugs, both treated and untreated, as they fill the spike hole better, absorb moisture, swell and stay in the hole and are less liable to split the tie than hardwood.

Tie plugs should be driven to full depth and with the widened head parallel with the tie so as to take up any enlarging of the hole back of the spikes.

Treated tie plugs should be used in all treated ties.

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[11] Adopted, Vol. 24, 1923, pp. 256, 1148; Vol. 28, 1927, pp. 189, 1288.
[12] Adopted, Vol. 26, 1925, pp. 1079, 1433.

MATERIAL

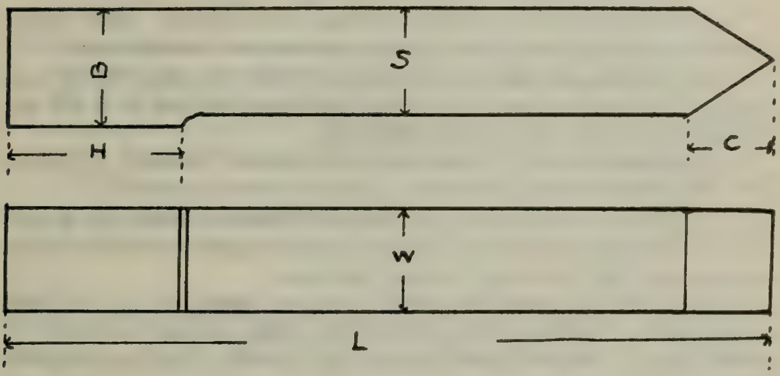
1. Kinds of Wood.—The following kinds of wood are suitable for use in the manufacture of tie plugs: Ash, Beech, Birch, Catalpa, Cedar, Cherry, Chestnut, Cypress, Elm, Fir, Gum, Hackberry, Hemlock, Larch, Locust, Maple Mulberry, Oak, Pine, Poplar, Redwood, Sassafras, Spruce, Sycamore and Walnut.

GENERAL QUALITY

2. Tie plugs shall be sound, seasoned, straight grained, and free from knots or other defects.

DESIGN

3. The following general design is recommended:



DIMENSIONS

4. Tie plugs shall be of two general sizes for ⅝-inch and 9/16-inch standard spikes. Before manufacture producers will ascertain which of the two sizes are required. The following dimensions are recommended:

	B	*S*	*H*	*C*	*W*	*L*	(See diagrams)
For ⅝″ Spike....	11/16″	⅝″	1″	½″	⅝″	4½″ to 5″	or same length as spike used
For 9/16″ Spike....	⅝″	9/16″	1″	½″	9/16″	4½″ to 5″	or same length as spike used

MANUFACTURE

5. Tie plugs shall be made in multiple or singly.

DELIVERY

6. Multiple plugs shall be shipped in bundles of multiples of 100 securely tied by wire. Single plugs shall be shipped in bags as desired by the purchaser.

[13]DIMENSIONS OF TIES

(1) The size of ties most widely used under heavy traffic (main track in main lines) has increased since 1905 from 6″x8″x8 to 7″x9″x8′6″.

(2) Owing to the many variables involved, including strength of timber in its average condition in track, condition of roadbed, etc., it is not possible to calculate a design for a tie in the sense that a bridge member is designed.

(3) For heavy traffic, ties should have a minimum thickness of 7″, a maximum width of 12″ and a length of at least 8′6″ or possibly 9′.

(4) A space of 10″ between tops of ties allows sufficient room for tamping; the maximum of bearing area on the ballast may be secured by the use of the wider and longer ties laid with this spacing.

[14]PROPER SIZE OF HOLES FOR PREBORING

(1) Because it is very difficult to make chisel-pointed spikes follow ¼ inch and ⅜ inch holes, these sizes are too small for practical use.

(2) In hardwood ties, using $\frac{9}{16}$ inch by 6 inch cut spikes, the $\frac{7}{16}$ inch holes give greatest resistance to vertical pull; using ⅝ inch by 6 inch cut spikes, ½ inch holes give greatest resistance.

In softwood ties, the $\frac{7}{16}$ inch holes give greatest resistance to vertical pull with both $\frac{9}{16}$ inch by 6 inch and ⅝ inch by 6 inch cut spikes.

(3) In hardwood ties, using $\frac{9}{16}$ inch by 6 inch cut spikes, the $\frac{9}{16}$ inch holes give greatest resistance to horizontal thrust; using ⅝ inch by 6 inch cut spikes, the ⅝ inch holes give greatest resistance.

In softwood ties, using $\frac{9}{16}$ inch by 6 inch cut spikes, the $\frac{9}{16}$ inch holes give greatest resistance to horizontal thrust; using ⅝ inch by 6 inch cut spikes, there is little difference between the ½ inch, $\frac{9}{16}$ inch and ⅝ inch holes.

(4) Disturbance of the wood fibers is much less where spikes are driven in holes $\frac{7}{16}$ inch in diameter or larger. In general there is the least damage to the fiber when the largest size holes are used.

(5) Spike holes should be bored entirely through the ties except in the case of ties for use in direct current electric lines having covered track. Under such conditions it has been found that spikes corrode badly due to electrolysis when the spike holes are bored entirely through the ties.

It is recommended:

(a) That ½ inch holes be bored in hardwood ties for $\frac{9}{16}$ inch cut spikes.

(b) That $\frac{9}{16}$ inch holes be bored in hardwood ties for ⅝ inch cut spikes.

(c) That $\frac{7}{16}$ inch holes be bored in softwood ties for $\frac{9}{16}$ inch cut spikes.

(d) That ½ inch holes be bored in softwood ties for ⅝ inch cut spikes.

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[13] Adopted, Vol. 25, 1924, pp. 128, 1221

[14] Adopted, Vol. 30, 1929, pp. 320, 1372.

COMMITTEE IV

RAIL

[1]DEFINITIONS

IRON

Commercial Iron.—The element iron as pure as it can be commercially produced.

Pig Iron.—The product of the blast furnace in which iron ore, limestone and coke are heated together and the molten impurities removed as slag.

Pig iron contains a high percentage of carbon ranging from 3.5 to 4.0 per cent.

Wrought Iron.—A commercial iron sufficiently free from carbon and other impurities to be malleable when such metal is manufactured through the reduction of iron ores, or the refining of cast iron at a temperature so low that it is obtained in a pasty condition and, therefore, mechanically mixed with a considerable amount of slag formed during the operation.

Most of the slag is removed by hammering and rolling of the balls of metal removed from the furnace. Its carbon content varies usually from 0.05 to 0.10 per cent.

STEEL

Steel.—Steel is purified pig iron, which unlike wrought iron has been cast while in a molten state, and in which the carbon and impurities present in the original pig iron have been reduced to such a point that the ingot cast is capable of being forged or rolled into blooms, slabs or rails.

The amount of carbon in steel is controlled in the process of manufacture and varies from 0.10 to 1.50 per cent, depending on the use to be made of the product.

Simple Steel.—Often called Carbon Steel (or plain steel), consisting chiefly of iron, carbon, and manganese.

Other elements are always present, but are not essential to the formation of the steel, and the content of carbon or manganese, or both, may be very small.

Alloy Steel.—A steel that contains one or more elements other than carbon in sufficient proportion to modify or improve substantially and positively some of its useful properties.

These steels, since they contain a special element, are sometimes called special steels.

MANUFACTURE

Bessemer Converter.—A pear-shaped tilting furnace for refining a charge of liquid pig iron by the Bessemer process in which no extraneous fuel is burned.

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[1] Adopted, Vol. 28, 1927, pp. 920, 981, 1349; Vol. 30, 1929, pp. 1271, 1482.

Amendments to Definitions (Vol. 31, p. 1455; Bul. 327, p. 10).

BESSEMER PROCESS:

(a) ACID BESSEMER.—Steel made by the process of blowing air through liquid pig iron, whereby the carbon, manganese and silicon are oxidized to the extent desired and removed in the form of slag.

More carbon is removed than is finally required and the metal is then recarburized. The converter (furnace) has an acid lining, usually ganister or other highly siliceous material. Phosphorus and sulphur are not removed in the refining process.

(b) BASIC BESSEMER.—Steel made by a process similar to the Acid Bessemer process excepting that the converter lining is basic, usually either magnesite or burned dolomite, and phosphorus is oxidized and removed in the basic slag.

The removal of sulphur is uncertain.

OPEN-HEARTH FURNACE.—A furnace having a hearth exposed to the flame, so that any piece of steel or other metal placed upon the hearth is exposed openly to the action of burning gases.

OPEN-HEARTH PROCESS:

(a) ACID OPEN-HEARTH.—A mixture of pig iron and scrap is charged into the furnace and melted.

The furnace is lined with a siliceous material (sand). In the refining of the molten steel, the carbon is generally brought considerably below the percentage ultimately required. The metal is thereafter recarburized to the desired amount. The slag contains an excess of silica and is acid in character. This process demands careful selection of pig iron and scrap, if high grade steel is to be produced, as phosphorus and sulphur are not removed in refining on a silica bed.

(b) BASIC OPEN-HEARTH.—A charge of pig iron, scrap and limestone is melted in a furnace lined with a basic material usually either magnesite or burned dolomite.

After refining, the bath is recarburized. The slag is basic. The removal of phosphorus, and of sulphur to a lesser degree, being under control, a lower grade of pig iron and scrap may be used than in the Acid Open-Hearth process.

INGOT.—A special form of casting made for subsequent rolling and forging.

(a) HOT TOP OR SINK HEAD INGOT.—A type of ingot cast with large end up.

On top of the mold is placed a cast iron box lined with refractory material, the mold being filled with steel to within a few inches of the top of this box.

(b) INGOT STOOL.—The plate or base upon which an open bottom mold stands.

DEOXIDIZED STEEL (Dead-Setting Steel).—Steel in which oxygen has been removed from the iron.

The chief deoxidizers are manganese, silicon and titanium.

ANNEALING.—Heating above the "critical temperatures" followed by relatively slow rate of cooling.

BILLET.—A small bloom; a short bar of iron or steel with a rectangular section.

A billet is rolled of the size and weight required for the finished article which is to be produced from it.

BLED INGOT.—An ingot which has fallen over while solidifying, or has met with some other mishap, allowing the liquid interior to escape, thus leaving the walls intact.

It may sometimes bleed at the top and sometimes at the bottom, but usually at the top.

Bloom.—An intermediate product made by the rolling of the ingot.

In rail making it is usually understood that a bloom is about eight inches square, but it might be seven inches or ten inches, rectangular and not square in shape.

Blow.—A charge made in the Bessemer converter.

Burrs.—The rough edges remaining on a rail when sawn hot, also formed by the drill in making bolt holes.

The sawing of the metal leaves very sharp and jagged edges at the end of rails, which must be removed.

Butt.—An indefinite term, meaning sometimes the lower part of an ingot, in which case it is called the "butt of the ingot"; a butt, pure and simple, is an ingot so short that it is incapable of being rolled; sometimes applied to the shortest ingot of the heat, much shorter than the others, but still long enough to be rolled.

Cambering Machine.—A machine by which the hot rails are given the curvature necessary to compensate for the unequal cooling of head and base, so that they will cool as nearly straight as possible.

Cinder Heat (Burned Ingot).—The heating of a bloom or ingot in a heating furnace to such a degree that a certain amount of melted slag or oxide is formed on the outer surface of the piece.

Critical Temperatures.—In the cooling of iron or steel, there is an abrupt arrest in the cooling at certain temperatures which is caused by the evolution of considerable heat in the metal, brought about by some internal crystalline or molecular transformation inside the mass.

These temperatures are called "Critical Temperatures."

Crop End.—A piece cut off from the end of a rail after rolling.

Cropping.—The act of shearing or sawing off a certain amount of metal from the end of the bloom after being rolled from an ingot, or from the end of a rail after it is finished.

Fishing (or Male) Templet.—A templet used to determine whether the rail section is accurately formed in the fishing spaces to receive the joint bars.

Gagging.—A term used to describe the work done at the straightening press by the use of a steel "gag" or tool upon the rail for the purpose of taking a bend out of a rail.

Heat.—A charge of molten cast iron made in a Bessemer converter; or the steel scrap, pig or molten iron, limestone and fluxes in the open-hearth furnace; and the resulting molten steel which is poured or tapped from the furnace.

Also refers to the ingots charged into the soaking pits, or the blooms charged into the reheating furnace.

Lumpy.—The condition of a rail having a succession of short and sharp bends.

Pass.—The passage of the ingot through the blooming rolls or the passage of the bar through the rail rolls.

Also refers to the openings in the various rolls or roll trains, which give the hot metal the shape desired.

Piping.—The formation of a cavity in the upper interior of an ingot, caused by shrinkage of the liquid metal when solidifying.

Rail Section.—The shape of the end of a rail cut vertically at right angles to the length.

Reheating of Blooms.—(Some steel mills give the blooms a "wash heat," or in other words, the blooms are placed in the furnace while hot after leaving the bloom shear, and kept in the furnace just long enough to equalize the temperature inside and out of each bloom for rolling into rails.)

Segregation.—The concentration of the carbon and impurities (in solution) into that portion of a metal casting which solidifies last.

Segregation may be positive or negative; positive when the preceding condition prevails and negative when any part of the ingot has less than the average amount of carbon and impurities.

Shrinkage Allowance.—The extra length to which a rail is cut when hot, immediately after rolling, so that it will be the desired length when cold.

Soaking Pit.—A furnace in which the ingot, after being stripped, is placed for the purpose of equalizing the temperature throughout the mass.

Teeming, Teemed.—The pouring of the metal from the ladle into the ingot.

Templet.—Usually a piece of metal cut out to the exact size and shape of the rail. It may be the exact size and shape of the rail when cold, or when hot, or the reverse of the shape, so as to fit on the outside, either when cold or hot.

Train.—A series of pairs or sets of rolls connected together, and driven by the same motor or engine.

TESTING

Compressive Strength.—The maximum compressive stress which a material is capable of developing.

Ductility.—The percentage elongation and percentage reduction of area are a measure of the ductility of a metal, usually varying inversely with the tensile strength.

Elastic Limit.—The greatest stress which a material is capable of developing without a permanent deformation remaining upon complete release of the stress.

Elongation.—The elongation is measured in percentage of the original test section and is commonly the amount of stretch which will occur in the material when pulled apart by tension.

Hardness.—The resistance to indentation or abrasion or attrition (wear from rubbing or crushing).

Ladle Test Ingot.—A small casting made when the metal is teemed, to be used for chemical test purposes.

Modulus of Elasticity.—The ratio, within the elastic limit of a material, of stress to corresponding strain.

Proportional Limit.—The greatest stress which a material is capable of developing without a deviation from the law of proportionality of stress to strain.

Permanent Set.—If loaded beyond the elastic limit the bar will not return to its original length and shape.

It is said to have a permanent set.

Reduction (or contraction) **of Area.**—The reduction of area refers to the area at the point of rupture, usually reported in per cent.

The reduction of area is the original area minus the area of smallest cross-section after fracture and this divided by the original area is the "percentage reduction of area."

Strain.—The change per unit of length in a linear dimension of a body, which change accompanies a stress. Strain is measured in inches per inch of length (millimeters per millimeter).

Stress.—The intensity (measured per unit area) of the internal distributed forces or components of force which resist a change in the form of a body.

Stress is measured in force per unit area (pounds per square inch, kilograms per square millimeter, etc.).

Tensile Strength.—The maximum tensile stress which a material is capable of developing.

Tolerance.—An allowance made for a small variation from dimensions specified.

Yield Point.—The stress in a material at which there occurs a marked increase in strain without an increase in stress.

RAIL FAILURES

Compound Fissure.—A horizontal fissure which in developing extends into a plane other than horizontal.

Detail Fracture.—A fracture caused by the gradual breaking of the metal under alternate bending stresses.

Horizontal Fissure.—A horizontal progressive fracture originating in the interior of the head of the rail, usually indicated on side of head by longitudinal seam or crack and by flow of metal.

Piped Rail.—A rail in which the sides of the shrinkage cavity formed in the ingot are closely pressed together in the web of the rail but not welded.

Transverse Fissure.—A crosswise break starting from a center or nucleus inside of the head of the rail from which the fracture spreads outward.

The broken rail will show a smooth oval or round spot within the head, substantially at right angles to the axis of the rail, which will be bright when first exposed to the air. The nucleus will show a typical crystalline fracture and the growing portion a typical detail fracture.

Note.—For definitions of other failures see form 402-A.

MISCELLANEOUS

Batter:

Half Inch Point Batter.—The distance in thousandths of an inch between the bottom of a straight edge 12 to 24 inches long, applied along the center line of the worn surface on the top of the rail (with one end coinciding with the end of the rail) and the top of the rail measured at a point ½ inch from the end of the rail.

End Batter.—The distance at the end of the rail measured as for half inch point batter.

TOTAL BATTER.—The sum of half inch point batter and end batter.

(A) For welding, resawing and renewal purposes half inch point batter taken with a taper gage in 64ths of an inch will be sufficient.

(B) For statistical purposes the batter should be measured with a dial micrometer in thousandths of an inch. For uniformity the use of standard batter gage is recommended.

CANTING OF RAIL.—The inclination inwardly of the rail, accomplished by inclined tie plates, or by adzing the ties.

END CHIPPING.—The loosening of the metal on the top or gage side of the end of a rail subjected to traffic.

END OVERFLOW.—The projection into the joint gap of metal at the top of the gage side of the head of the rail brought about by impact of wheels under traffic.

FISHING SPACE.—The space between the head and base of rail occupied by the splice bar.

JOINT BAR.—A steel member, embodying beam-strength and stiffness by its structural shape and material, commonly used in pairs for the purpose of splicing rail ends together, and holding them accurately, evenly and firmly in position with reference to surface and gage-side alinement.

JOINT GAP.—The distance in 64ths inch between the ends of contiguous rails measured at a point about 5/8 inch below the top of the rail.

MACROGRAPH.—A graphic reproduction of any object which has not been magnified more than 10 diameters.

NOTE.—When it is desired to indicate that it is a photographic reproduction, the term "photomacrograph" may be employed.

MAGNIFICATION.—The ratio of the size of the image to that of the subject.

NOTE.—Magnification is generally expressed in "Diameters," thus "×100" or "100 diameters."

MICROGRAPH.—A graphic reproduction of any object magnified more than 10 diameters.

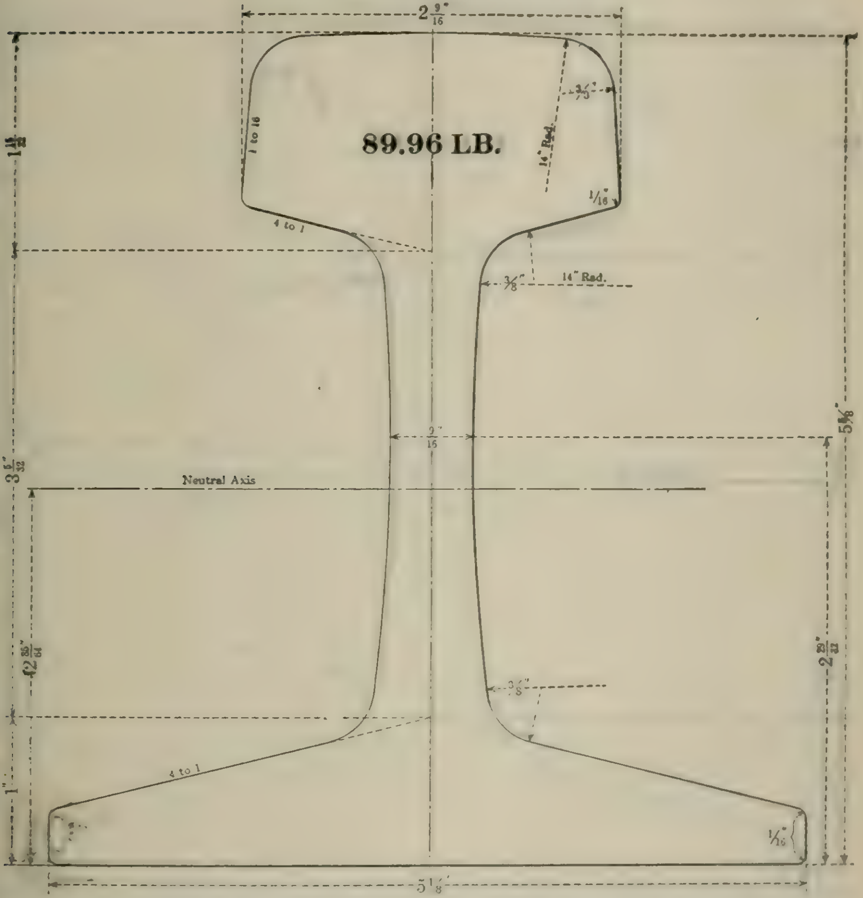
NOTE.—When it is desired to indicate that it is a photographic reproduction, the term "photomicrograph" may be employed.

MILLING RAIL.—The cutting with a milling hob of the ends of the rails to correct roughness and inaccuracies of sawing.

SPRING WASHER.—A member designed to prevent by spring action the backward movement of the nut and looseness in the bolted members due to wear, stretch, rust or other deterioration.

[2]STANDARD RAIL SECTIONS

RAIL SECTION—R.A.-A.—90-LB.



Area:			
Head	=3.20	sq. in.	36.2%
Web	=2.12	" "	24.0%
Base	=3.50	" "	39.8%
Total	=8.82	" "	100.0%

Moment of Inertia	38.7
Section Modulus, Head	12.56
" " Base	15.23
Ratio M.I. to Area	4.39
Ratio Sec. Mod. to Area	1.42

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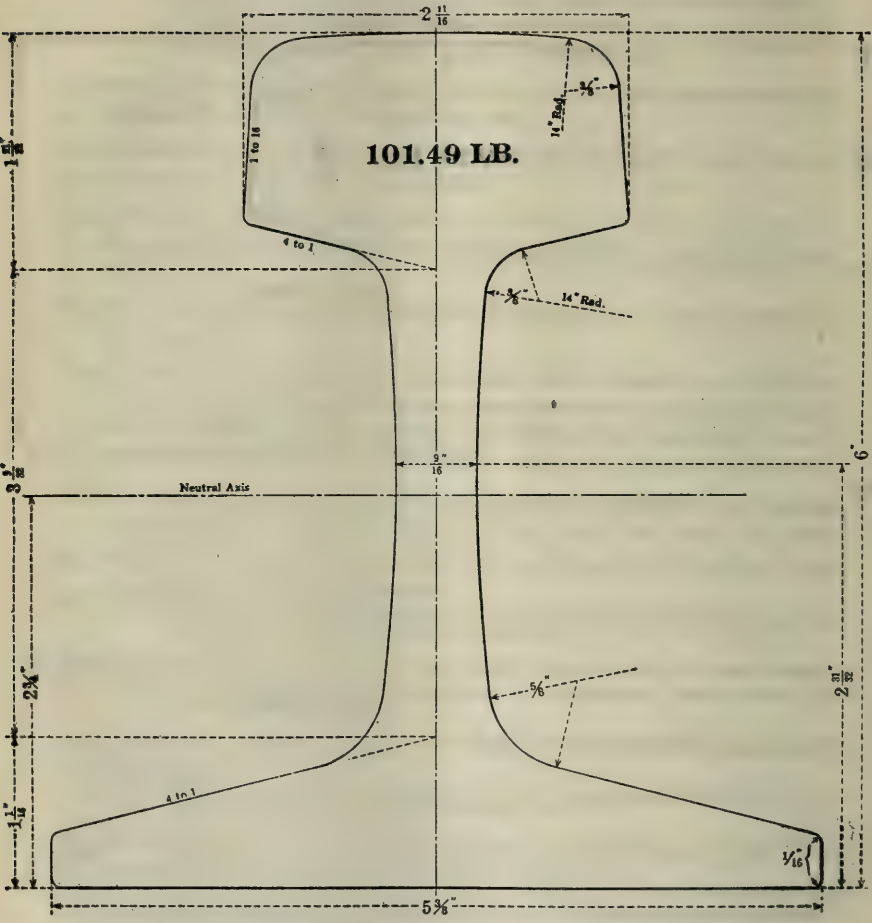
[2] Adopted, Vol. 16, 1915, pp. 397, 1117; Vol. 21, 1920, p. 1455; Vol. 25, 1924, pp. 392, 1287.

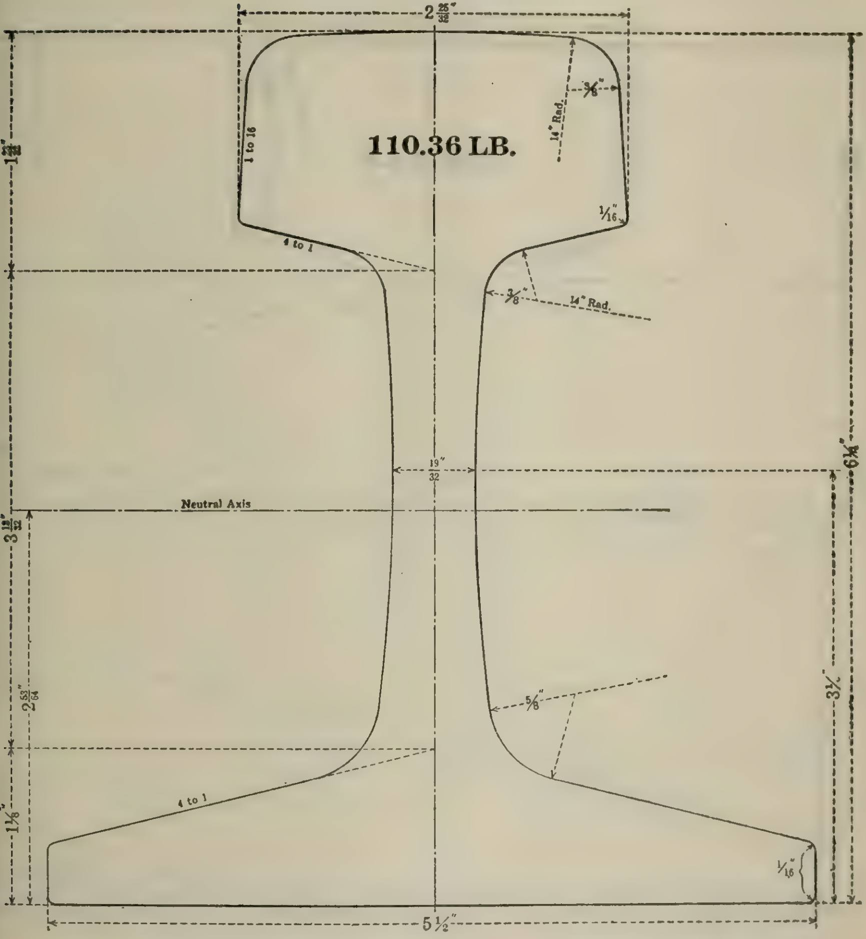
RAIL SECTION—R.E.—100-LB.



Area: Head	=3.80	sq.	in.	38.2%
Web	=2.25	"	"	22.6%
Base	=3.90	"	"	39.2%
Total	=9.95	"	"	100.0%

Moment of Inertia	49.0
Section Modulus, Head	15.1
" " Base	17.8
Ratio M.I. to Area	4.92
Ratio Sec. Mod. to Area	1.52

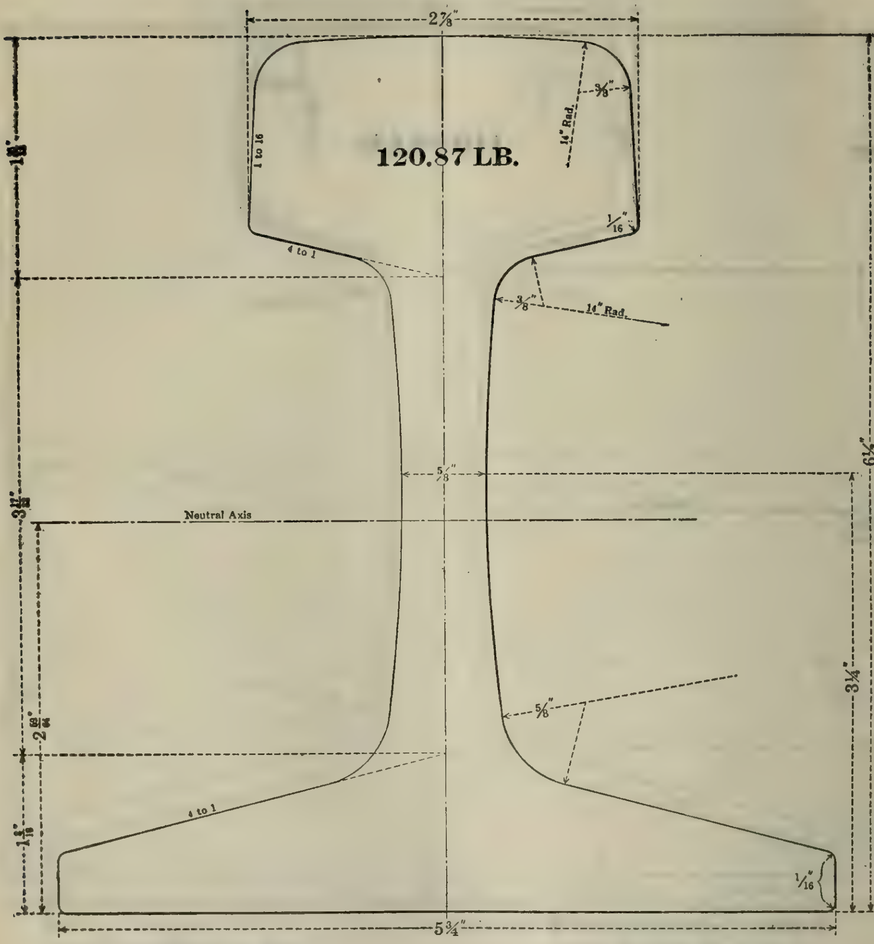
RAIL SECTION—R.E.—110-LB.



Area:				
Head	=4.04	sq.	in.	37.4%
Web	=2.49	"	"	23.0%
Base	=4.29	"	"	39.6%
Total	=10.82	"	"	100.0%

Moment of Inertia	57.0
Section Modulus, Head	16.7
" " Base	20.1
Ratio M.I. to Area	5.27
Ratio Sec. Mod. to Area	1.65

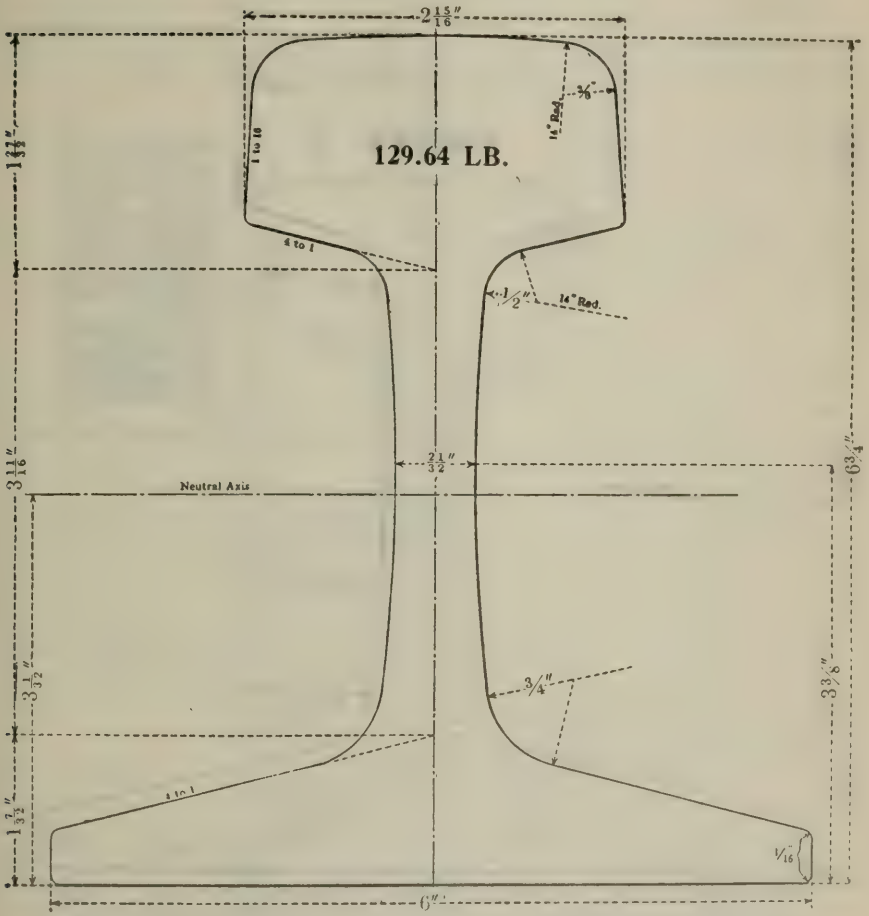
RAIL SECTION—R.E.—120-LB.



Area: Head=4.40 sq. in. 37.1%
Web =2.69 " " 22.7%
Base =4.76 " " 40.2%
Total =11.85 " " 100.0%

Moment of Inertia	67.6
Section Modulus, Head	18.9
" " Base	23.1
Ratio M.I. to Area	5.71
Ratio Sec. Mod. to Area	1.59

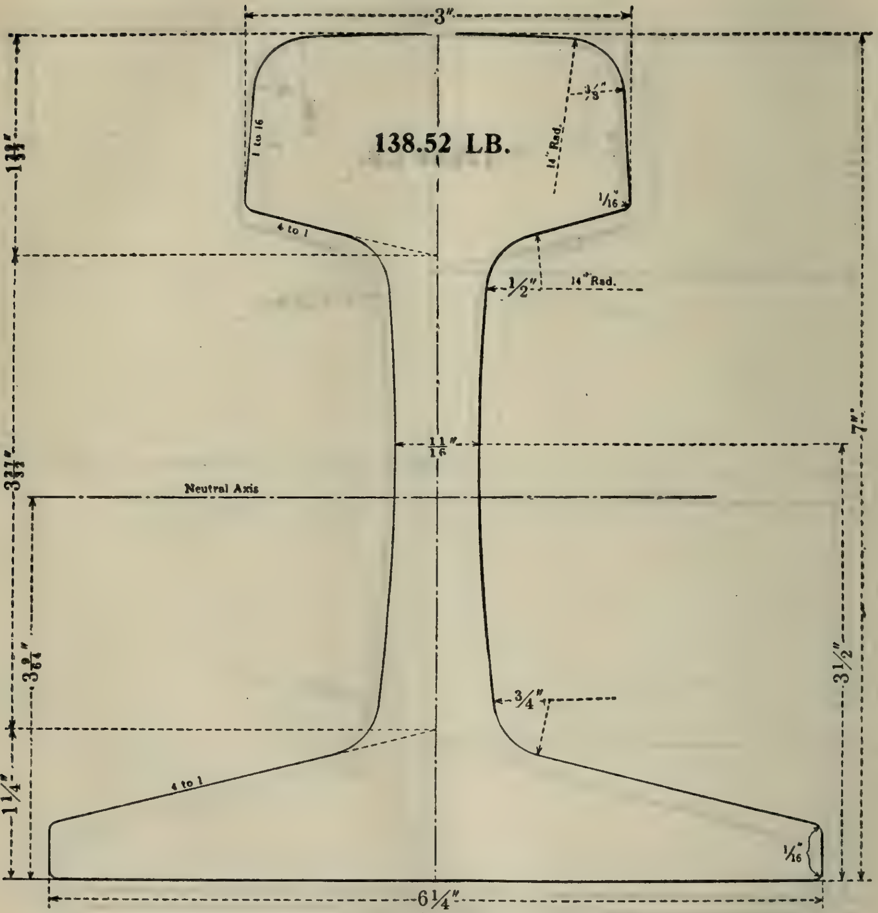
[3]RAIL SECTION—R.E.—130-LB.



Area;			
Head	= 4.63 sq. in.	36.4%	
Web	= 3.02 "	"	23.8%
Base	= 5.06 "	"	39.8%
Total	= 12.71 "	"	100.0%

Moment of Inertia	77.4
Section Modulus, Head	20.8
" " Base	25.6
Ratio M. I. to Area	6.09
Ratio Sec. Mod. to Area	1.64

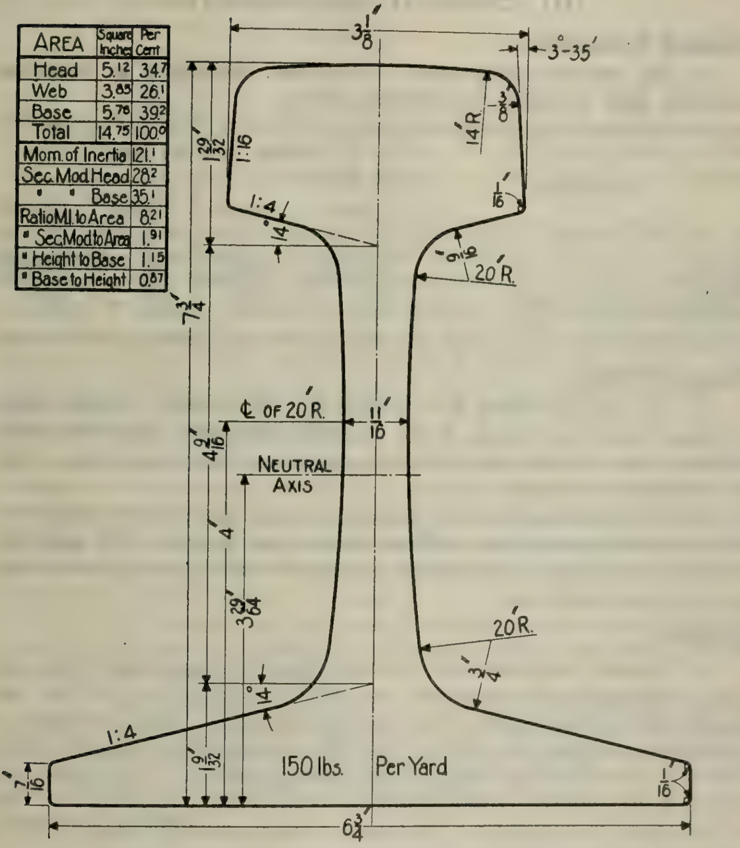
RAIL SECTION—R.E.—140-LB.



Area:			
	Head	=4.93 sq. in.	36.3%
	Web	=3.28 " "	24.1%
	Base	=5.37 " "	39.6%
	Total	=13.58 " "	100.0%

Moment of Inertia	89.2
Section Modulus, Head	23.1
" " Base	28.4
Ratio M.I. to Area	6.56
Ratio Sec. Mod. to Area	1.70

RAIL SECTION R.E.—150 -LB.



AREA	Square Inches	Per Cent
Head	5.12	34.7
Web	3.85	26.1
Base	5.78	39.2
Total	14.75	100.0
Mom. of Inertia		121.1
Sec. Mod. Head		28.2
" " Base		35.1
Ratio M.I. to Area		8.21
" Sec. Mod. to Area		1.91
" Height to Base		1.15
" Base to Height		0.87

[3]STANDARD SPECIFICATIONS FOR OPEN-HEARTH CARBON STEEL RAILS—1925

(I) INSPECTION

Access to Works

1. Inspection and tests shall be made at the works of the manufacturer before shipment, and the works management shall afford all reasonable facilities for determining the satisfactory quality of rails accepted.

(II) CHEMICAL REQUIREMENTS

Chemical Composition

2. The chemical composition of the steel, determined as prescribed hereafter, shall be within the following limits:

Constituents	Weight in lb. per yard			
	70-84	85-100	101-120	121-140
Carbon	0.53-0.70	0.62-0.77	0.67-0.83	0.72-0.89
Manganese	0.60-0.90	0.60-0.90	0.50-0.90	0.50-0.90
Phosphorus, not to exceed	0.04	0.04	0.04	0.04
Silicon, minimum	0.15	0.15	0.15	0.15

Average Carbon

3. (a) In any rolling it is desired that the number of heats above the mean carbon percentage of the specified range shall be at least equal to the number of heats below the mean, and that the average carbon shall be as high as the mean.

(b) For information only, the manufacturer shall furnish the carbon and manganese analysis on drillings taken from both the "O" and "M" positions of the head at the top end of the "A" rail of the last full ingot rolled on each tenth heat.

Analyses

4. Separate analyses shall be made from drillings taken from test ingots representing the second and one of the last full ingots of the heat to determine the percentage of carbon and manganese. The percentage of phosphorus, sulphur, and silicon shall be determined on equally mixed drillings from the test ingots. The average analysis of the ladle test ingots shall conform to the chemical requirements. A portion of the drillings shall be furnished to the inspector upon request for check analysis.

(III) PHYSICAL REQUIREMENTS

Physical Qualities

5. Ductility and resistance to impact will be determined by the standard A.R.E.A. drop testing machine, with test specimens from four feet to six

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[3] Adopted, Vol. 3, 1902, pp. 204, 208; Vol. 5, 1904, pp. 465, 469; Vol. 6, 1905, p. 190; Vol. 7, 1906, pp. 549, 552, 559, 562, 573, 576; Vol. 10, Part 1, 1909, pp. 374, 393; Vol. 11, Part 1, 1910, pp. 237, 252, 255; Vol. 12, Part 1, 1911, p. 467; Vol. 12, Part 2, 1911, p. 12; Vol. 13, 1912, pp. 853, 1017; Vol. 14, 1913, pp. 181, 1103; Vol. 15, 1914, pp. 158, 375, 1104; Vol. 16, 1915, pp. 157, 159, 1117; Vol. 21,. 1920, pp. 1070, 1455; Vol. 26, 1925, pp. 619, 1418.

Amendment to Standard Specifications for Open-Hearth Carbon Steel Rails—1925 (Vol. 31, pp. 1453, 1457; Bul. 327, p. 11).

feet long cut from the top of the "A" rails from the second, middle and last full ingots of each heat. The distance between supports shall be three feet for sections under 106 lb. For sections 106 lb. and over it shall be four feet.

Temperature of the test pieces must not exceed 100 deg. Fahr.

Drop Test

6. The test specimens shall be placed preferably base upwards on the supports and subjected to one blow from the tup falling free from the following heights:

For 81- 90 lb. rail, inclusive	18 ft.
" 91-100 lb. " "	19 ft.
" 101-120 lb. " "	20 ft.
" 121-140 lb. " "	22 ft.

If all these specimens endure the above tests without fracture, all the rails of the heat will be accepted subject to final inspection for surface, section and finish.

If one of the three specimens fail, all the "A" rails of the heat will be rejected. Specimens shall then be cut from the bottom end of the same "A" rails or the top end of the "B" rails and tested. If any of these tests fail, the "B" rails of the heat will be rejected. Three additional specimens shall then be taken from the bottom end of the "B" rails or the top end of the "C" rails. If all these tests stand, the balance of the heat will be accepted. If any of these tests fail, the entire heat shall be rejected.

Elongation and Permanent Set

7. (a) One of the three test specimens shall be given a sufficient number of blows to determine, for information only, the exhausted ductility, reported inch by inch over the entire six inches gaged. No ductility readings will be taken between blows. The other two specimens shall be nicked and broken. The fracture of each specimen shall be examined to determine the requirements of Section 8.

(b) For information only, the permanent set measured by middle ordinate in inches in a length of three feet shall be recorded after the first blow on all test specimens.

(c) For information only, one of the three test specimens shall be tested by Brinell indentation upon the head of the rail, and the diameter of the indentation shall be entered upon the test record. The ball shall be 19 millimeters in diameter and the pressure 100,000 lb.

Interior Condition

8. If the fracture on any test specimen exhibits seams, laminations, cavities, interposed foreign matter, or a distinctly bright or fine-grained structure, all top rails represented shall be classified as "X-Rayls."

Classification

9. *No. 1 Rails*

No. 1 rails shall be free from injurious defects and flaws of all kinds.

X-Rayls

Rails as described in Sections 8 and 15 (c).

No. 2 Rails

Rails which conform to the following requirements will be accepted as No. 2 rails:

(a) Rails which do not contain surface imperfections in such number or of such character as will in the judgment of the inspector render them unfit for recognized uses.

(b) Rails arriving at the straightening presses with sharp kinks of greater camber than that indicated by a middle ordinate of six inches in 39 feet.

(IV) DETAILS OF MANUFACTURE

Discard

10. Sufficient discard should be taken from the ingot to insure freedom from injurious segregation and pipe.

Lengths

11. Standard length of rails shall be 39 feet at a temperature of 60 deg. Fahr. Eleven per cent of the entire order will be accepted in shorter lengths varying by one foot from 38 feet to 25 feet. A variation of $\frac{3}{8}$ inch from the specified length will be allowed, except that on fifteen per cent of the order a variation of $\frac{7}{16}$ inch will be allowed.

Section

12. Section of rails shall conform as accurately as possible to the templets furnished by the purchaser. A variation of $\frac{1}{64}$ inch less or $\frac{1}{32}$ inch greater than the specified height will be permitted. A variation of $\frac{1}{16}$ inch in the length of either flange will be permitted, but the variation in total width of base must not exceed $\frac{1}{16}$ inch. No variation will be allowed in dimensions affecting the fit of the joint bars, except that the fish templet approved by the purchaser may stand out not to exceed $\frac{1}{16}$ inch laterally.

Weight

13. A variation of one-half of one per cent from the calculated weight of section as applied to the entire order will be allowed.

Drilling

14. Circular holes for joint bolts shall be drilled to conform to the drawings and dimensions furnished by the purchaser. A variation of $\frac{1}{32}$ inch in the size and location of bolt holes will be allowed.

Finishing

15. (a) All rails shall be smooth on the heads, straight in line and without twists, waves or kinks. The supports for rails in the straightening presses shall have flat surfaces and be free from hollow places, bends or crooks, and shall be spaced not less than 60 inches. When placed head up on a horizontal surface, rails that are slightly higher at the ends than the middle will be accepted, provided they contain a uniform sweep, the middle ordinate of which does not exceed 1¼ inches in 39 feet. They shall be sawed square at the ends, a variation of not more than $\frac{1}{32}$ inch being allowed, and burrs shall be entirely removed.

(b) Rails presented for inspection which do not conform to the requirements of Section 14 or Section 15 (a) may be reconditioned by the mill, provided they can be made to fully meet the requirements.

(c) When any finished rail shows conditions as described in Section 8 at either end or at any drilled hole, it shall be cut back to sound metal, and accepted as an "X-Rayl."

Branding

16. Brands made so plain and sharp that they may be read as long as the rails are in service shall be rolled on or hot stamped into the side of the web of each rail in accordance with the following requirements and to indicate:

(a) Name of the manufacturer, the month and year of manufacture, and the weight and type of section of rail as rolled.

(b) The heat number and the ingot number as rolled shall be stamped in the web of each rail where it will not be covered by the joint bars.

(c) The top rails shall normally be lettered "A," and succeeding ones "B," "C," "D," "E," etc., consecutively, but in case top discard is greater than normal, the rail lettering shall conform to the amount of discard, the top rail becoming "B," or other succeeding letter to suit the condition.

(d) All rails shall be branded "O-H" in addition to other marks.

Classification Markings

17. (a) Rails accepted as No. 2 rails shall have the ends painted white and shall be stamped with the figure 2 on both end faces.

(b) Rails accepted as "X-Rayls" shall have the ends painted brown and shall be stamped with the letter "X" on both end faces.

(c) "A" rails shall have both ends painted yellow.

(d) No. 1 rails less than 39 feet long shall have both ends painted green.

(e) All rails of heat whose carbon content exceeds the mean carbon percentage of the specific range shall have both ends painted blue.

Individual rails shall be painted only one color, according to the order of precedence listed above.

Loading

18. Rails shall be carefully handled in such manner as to avoid injury and shall be loaded as follows:

(a) No. 1 low carbon rails shall be loaded in separate cars.
(b) No. 1 high carbon rails shall be loaded in separate cars.
(c) No. 2 rails shall be loaded in separate cars.
(d) "X-Rayls" shall be loaded in separate cars.
(e) No. 1 "A" rails shall be loaded in separate cars.
(f) No. 1 short rails shall be loaded in separate cars.

No sub-division by classification markings other than listed above is necessary for separate loading.

Mill Practices

19. The entire process of manufacture shall be in accordance with the best current state of the art. It is expected that thoroughly deoxidized dead-setting steel will be furnished, and that in every stage of manufac-

ture strict adherence to the standards of the best practice of the individual mill will be observed.

Should anything occur in the process of manufacture which, in the judgment of the inspector, varies detrimentally from regular care and practice, the inspector will immediately notify the chief inspector and the general superintendent of the mill, confirming such report in writing. If after full investigation the inspector is not satisfied as to the good quality of the rails in question, and the rails, complying in other respects to this specification, be loaded for shipment, the inspector will immediately forward a copy of this report to the purchaser.

Acceptance and Payment

20. (a) In order to be accepted the rails offered must fulfill all the requirements of this specification.

(b) No. 2 rails to the extent of eight per cent of the whole order will be accepted.

(c) Rails accepted will be paid for according to actual weights.

[4]RAIL INSPECTION

(I) INSPECTION FORCE

Rail inspectors shall be selected with care and men not familiar with rolling mill practice shall not be sent to inspect rails except under the supervision of an experienced rail inspector. As far as possible the inspections shall be made by the same men, as they then become familiar with the methods of manufacture peculiar to each mill, for no two mills follow the same procedure even though owned by the same company.

(1) Chief Rail Inspector.
(2) Three or more assistant inspectors as size of mill and rate of rolling may require.
(3) One or more checkers, depending upon rapidity of loading.
(4) One chemist if check analyses are made in mill laboratory.

(II) DUTIES OF INSPECTORS

(1) The Chief Rail Inspector shall supervise the inspection force, mill practice, drop tests and make records.

(2) One assistant inspector shall follow the mill practice closely, i. e., time of charging, time of tapping, cutting of tests, etc.; record any irregularities, such as too rapid pouring, charging cold ingots, rolling cold bloom, low finishing temperature, behavior of rails under straightening presses or or any other departures from good mill practice which may affect the service of the rails.

(3) One assistant inspector for night duty shall make drop tests if necessary and follow the mill practice.

(4) One or more assistant inspectors shall inspect the rails on the loading beds for surface defects, straightness, etc.

(5) One or more checkers shall record the number of rails of each heat accepted and loaded in each car. A record of the car number and the number of rails of each heat in the car shall be sent to the Division Engi-

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[4] Adopted, Vol. 23, 1922, pp. 636, 1124.

neer, the Supervisor, the Roadmaster or other officer to whom the rails are consigned. This prevents the loading of rails rolled from odd ingots, or the loading of more rails than were originally rolled in a heat, or the loading of rails from rejected heats. It also furnishes a check record of the location of the rails if at any time in the future it is desired to remove the rails of a particular heat for any cause whatever.

(6) A chemist shall make check analysis of drillings taken from corner of head of the rail, no rails being loaded until the check analysis is finished.

(7) The office to which the rail inspection force reports shall keep a record of the history of each heat in a convenient form, so the results obtained from the service of the rails may be traced to the manufacture of the steel or rails.

(8) Acceptance of heats meeting the technical requirements of specifications, but in the judgment of the inspector of inferior quality, shall be deferred pending decision of Engineer of Tests after full report and review of conditions; conversely, rejections of heats whose deficiencies may be technical only shall be similarly governed.

(9) The inspectors cannot be too careful and must exercise good judgment and all possible tact.

[5]SPECIFICATIONS FOR OPEN-HEARTH STEEL GIRDER RAILS OF PLAIN, GROOVED AND GUARD TYPES

(I) GENERAL SCOPE

These Specifications are intended to cover the manufacture of Open-Hearth Steel Girder Rails of Plain, Grooved and Guard Types, of the classes specified.

Girder Guard Rails shall be Class A.

Plain and Grooved Girder Rails under 135 lb. in weight per yard shall be specified either Class A or Class B.

Plain and Grooved Girder Rails of 135 lb. in weight per yard and heavier shall be Class C unless otherwise specified.

(II) MANUFACTURE

Process

101. The steel shall be made by the Open-Hearth process. The entire process of manufacture and testing shall be in accordance with the best current practice.

Bled Ingots

102. Bled ingots, and ingots or blooms which show the effects of injurious treatment, shall not be used.

Discard

103. A sufficient discard from the top of each ingot shall be made at any stage of the manufacture to obtain sound rails. When finished rails show piping, they may be cut to shorter lengths until all evidence of this is removed.

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[5] Adopted, Vol. 27, 1926, pp. 621, 1362; Vol. 30, 1929, p. 1235.

(III) CHEMICAL PROPERTIES AND TESTS

Chemical Composition

201. The steel shall conform to the following requirements as to chemical composition, according to the class specified in the order.

	Class A	Class B	Class C
Carbon, per cent......................	0.60-0.75	0.70-0.85	0.75-0.90
Manganese, per cent..................	0.60-0.90	0.60-0.90	0.60-0.90
Silicon, per cent......................	0.15-0.40	0.15-0.40	0.15-0.40
Phosphorus, per cent..................	Not over 0.04	Not over 0.04	Not over 0.04

Ladle Analyses

202. To determine whether the material conforms to the requirements specified in Section 201, an analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt. Drillings for analysis shall be taken not less than ⅛ inch beneath the surface of the test ingot. A copy of this analysis shall be given to the purchaser or his representative.

Check Analyses

203. A check analysis may be made as information from time to time by the purchaser from a test ingot or drillings therefrom furnished by the manufacturer.

(IV) PHYSICAL PROPERTIES AND TESTS

Impression Test Specimens

301. (a) Four representative sections of rail from each melt shall be selected by the inspector as test specimens.

(b) Excess scale on the head or web of the section shall be carefully removed.

Impression Test

302. (a) The head of each specimen shall be subjected to a pressure of 100,000 lb. (45,359KG), for a period of 15 seconds applied through a hardened steel ball 0.75 inch (19.05 mm.) in diameter.

Test Balls

(b) The steel test ball shall have a minimum Brinell hardness of 600 and it shall not be possible to attack the surface of the ball with an American Swiss Pillar File No. 2.

Permissible Variation in Test Balls

(c) When fractured, the ball shall show a fine, uniform grain, and the fracture shall resist file attack for at least ⅓ of its depth from the surface of the ball. The permissible variation in the diameter of the ball shall not be greater than 0.002 inch over or under the standard size and the permanent deformation under the required loading shall not be greater than 0.003 inch.

Depths of Impressions

(d) The average depth of impression obtained on the four (4) specimens shall not be more than 0.1496 inch (3.8 mm.) for Class A rails 0.1391 inch (3.5 mm.) for Class B rails, and 0.1338 inch (3.4 mm.) for Class C rails.

Re-Tests

303. If the average of the impression tests on the head of the section from any melt fails to conform to the requirements specified in Section 302-d the manufacturer may at his option test each rail from such melt by making an impression test on the web, as described in Section 302-a. Rails so re-tested which conform to the requirements as to depths of impression specified in Section 302-d shall be accepted.

(V) STANDARD SECTIONS, LENGTHS, AND WEIGHTS

Section

401. (a) The cold templet of the manufacturer shall conform to the specified section as shown in detail on the drawing of the purchaser, and shall at all times be maintained perfect.

(b) The section of the rail shall conform as accurately as possible to the templet, and within the following permissible variations:

(1) The height shall not vary more than $\frac{1}{64}$ inch under nor more than $\frac{1}{32}$ inch over that specified.
(2) The over-all width of head and tram shall not vary more than ⅛ inch from that specified. Any variation which would affect the gage line more than $\frac{1}{32}$ inch will not be allowed.
(3) The over-all width of base shall not vary more than ⅛ inch from that specified for widths less than 6½ inches; $\frac{3}{16}$ inch under for a width of 6½ inches; and ¼ inch under for a width of 7 inches.
(4) No change will be allowed in dimensions affecting the fit of splice bars, except that the fishing template approved by the purchaser may stand out not to exceed $\frac{3}{32}$ in. laterally.
(5) The base of the rail shall be at right angles to the web; and the convexity shall not exceed $\frac{1}{32}$ inch.

(c) When necessary on account of the type of track construction and notice to that effect has been given to the manufacturer, special care shall be taken to maintain the proper position of this gage line with respect to the outer edge of the base.

Length

402. (a) Unless otherwise specified, the lengths of rails at a temperature of 60 degrees Fahr. (15.5 C.) shall be 60 and 62 feet for those sections in which the weight per yard will permit, excepting girder guard rails, which shall be 30 and 32 feet unless otherwise specified.

(b) The lengths shall not vary more than ¼ inch from those specified.

(c) Shorter lengths, varying by one foot down to 40 feet for plain and grooved girder rails, and 24 feet for girder guard rails, will be accepted to the extent of 10 per cent by weight of each class on the order.

Weight

403. (a) The weight of the rails per yard as specified in the order shall be maintained as nearly as possible after conforming to the requirements specified in Section 401.

(b) The total weight of an order shall not vary more than 0.5 per cent from that specified.

(c) Payments shall be based on actual weights.

(VI) WORKMANSHIP AND FINISH

Straightening

501. (a) Rails on the hot beds shall be protected from water or snow and shall be carefully handled to minimize cold straightening.

(b) The distance between the rail supports in the cold-straightening presses shall not be less than 42 inches, except as may be necessary near the ends of the rails. The gag shall have rounded corners to avoid injury to the rails.

(c) Rails heard to snap or check while being straightened shall be at once rejected.

Finish

502. (a) Rails shall be smooth on the head, straight in line and surface without any twists, waves, or kinks, particular attention being given to having the ends without kinks or droop.

(b) All burrs or flow caused by drilling or sawing shall be carefully removed.

(c) Rails shall be free from gag marks and other injurious defects of cold-straightening.

(d) Any rails to be cold straightened showing sharp kinks, or greater camber than that indicated by the middle ordinate of 18 inches in 60 feet, shall be classed as No. 2 rails.

(VII) DRILLING, MILLING AND PUNCHING

Drilling

601. (a) Circular holes for splice bar bolts, bonds and tie rods shall be drilled to conform to the drawings and dimensions furnished by the purchaser and within the following permissible variations:

(b) The diameter of the bolt holes shall not vary more than $\frac{1}{32}$ inch over or under that specified. The diameter of the bond holes shall not be over the size specified, but may be $\frac{1}{32}$ inch under. The diameter of the tie rod hole shall not be less than that specified but may be $\frac{1}{16}$ inch over.

(c) The location of the bolt and bond holes shall not vary more than $\frac{1}{16}$ inch either longitudinally or vertically from that specified. The location of the tie rod holes shall not vary more than ¼ inch vertically and not more than ½ inch longitudinally from that specified.

(d) Bond holes shall be truly cylindrical and not conical.

Milling

602. The ends of the rail shall be milled. The plane of the finished end surface shall (in the direction of the width of the rail) be at right angles to the gage with a permissible variation of $\frac{1}{32}$ inch in 6 inches and (in the direction of the height of the rail) be inclined to the plane of the base so that the top edge of the head will project beyond the bottom edge of the base not less than $\frac{1}{32}$ inch nor more than $\frac{3}{32}$ inch.

Punching

603. Unless otherwise specified by the purchaser, the tie rod holes in Class A rails may be punched, and when so made, they shall be free from burrs, fins, etc. Punched tie rod holes shall not be less in diameter than specified, but may be not over ⅛ inch over size.

(VIII) CLASSIFICATION OF RAILS

No. 1 Rails

701. Rails which are free from injurious defects and flaws of all kinds shall be classed as No. 1 rails.

No. 2 Rails

702. (a) Rails which are rough on the head or which by reason of surface or other imperfections are not classed as No. 1 rails, shall be classed as No. 2 rails; providing they do not, in the judgment of the inspector, contain imperfections in such number and of such character as to render them unfit for No. 2 rail uses, and providing they conform to the requirements specified in Section 401.

(b) No. 2 rails will be accepted to the extent of 10 per cent by weight of the entire order.

(IX) MARKING AND LOADINGS

Marking

801. (a) The name or brand of the manufacturer, the year and month of manufacture, the letters "O.H.," the weight of the rail, and the section number, shall be legibly rolled in raised letters and figures on the web. The melt number shall be legibly stamped on each rail where it will not be covered subsequently by the splice bars.

(b) Both ends of all short-length No. 1 rails shall be painted green. Both ends of all No. 2 rails shall be painted white and shall have two heavy center-punch marks on the web at each end at such a distance from the end that they will not be covered subsequently by the splice bars.

Loading

802. (a) Rails shall be loaded in the presence of the inspector, and shall be handled in such a manner as not to bruise the flanges or cause other injuries.

(b) Rails of each class shall be placed together in loading.

(c) Rails shall be paired as to length before shipment.

(X) INSPECTION

Inspection

901. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

*GIRDER RAIL SECTIONS

(1) Satisfactory results have been obtained from the use of both "T" Rails and Girder Rails in Steam Railroad Track in paved city streets, but a very considerable expense is involved in the construction and maintenance of the paving, as vibration and movement of the rails under the traffic loads accelerate the disintegration of the paving. In order to minimize this detrimental effect it is of importance that the designs of rail sections and joints for this service should embody strength and rigidity. To most economically meet these requirements the following sections of Girder Rails, Joint Bars and accessories are recommended:

(2) Girder Rail Section—128-lb.—R.E.—7-A.

(3) Girder Rail Section—159-lb.—R.E.—9-A.

(4) Girder Guard Rail Section—174-lb.—R.E.—9-A.

(5) Joint Bars—159-lb.—R.E.—9-A, to be used with 159-lb.—R.E.—9-A Girder Rail Section, and 174-lb.—R.E.—9-A Girder Guard Rail Section.

(6) For Girder Rail construction the use of the 159-lb.—R.E.—9-A Section, except under light rail traffic where the use of 128-lb.—R.E.—9-A Section may be found more economical.

(7) In 9-inch Girder Rail construction the use of the 174-lb.—R.E.—9-A Section Girder Guard Rail which fishes with the 159-lb.—R.E.—9-A Section, for guarding frogs and on the inner rail of curves where the life of the outer rail is limited by flange wear rather than by top wear.

(8) **Bolt Holes** 1⅜-inch diameter drilled in both ends of the 159-lb.—R.E.—9-A Section and the 174-lb.—R.E.—9-A Section, with their center line 3¾ inches up from the base of the rail and spaced from the ends as follows: 2¾ inches-7½ inches.

(9) **Bolt Holes** 1⅛-inch in diameter drilled in both ends of the 128-lb.—R.E.—9-A Section with their center line 2¾ inches up from the base of the rail and spaced from the ends as follows: 2½ inches-4 inches-4 inches.

(10) **Joint Bars** of the sections shown as the 159-lb.—R.E.—9-A Joint Bars to be used with the 159-lb.—R.E.—9-A Section and 174-lb.—R.E.—9-A Section, 26 inches long, with bolt holes punched 2¾ inches-7½ inches-5½ inches-7½ inches-2¾ inches.

(11) **High Tensile Bolts** 1¼ inches in diameter for use with the 159-lb.—R.E.—9-A Section Rail.

(12) **High Tensile Bolts** 1 inch in diameter for use with the 128-lb.—R.E.—7-A Section Rail.

(13) **Ties** of the best grade and class, preferably treated.

(14) **Tie Plates** of sufficient size to prevent cutting of the ties.

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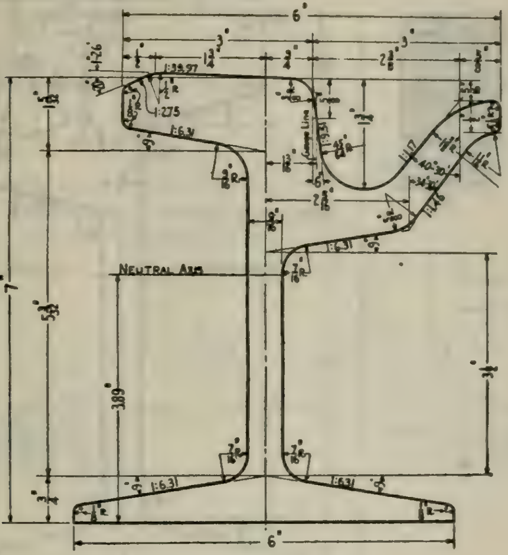
*Prepared in cooperation with American Electric Railway Association and Rail Manufacturers.

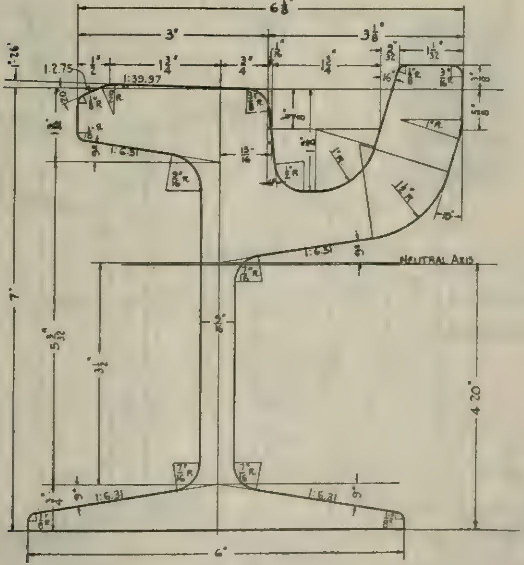
GIRDER RAIL SECTION—128-LB.—R.E.—7-A

AREA	Square Inches	Per Cent
Head	7.45	59.17
Web	2.10	16.68
Base	3.04	24.15
Total	12.59	100.00
Mom. of Inertia		78.0
Sec. Mod., Head		24.6
" " Base		20.1
Ratio M.I. to Area		6.20
" Sec. Mod. " "		1.38
" Height to Base		1.17
" Base to Height		0.85



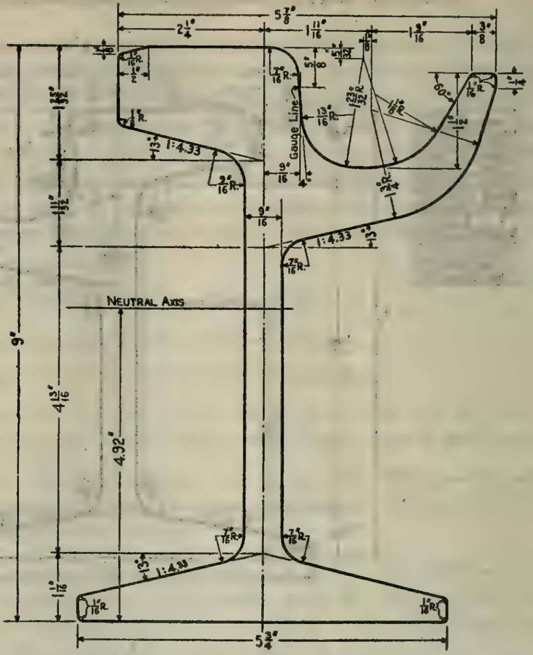
GIRDER RAIL SECTION—149-LB.—R.E.—7-A

AREA	Square Inches	Per Cent
Head	9.47	64.77
Web	2.00	13.68
Base	3.15	21.55
Total	14.62	100.00
Mom. of Inertia		87.7
Sec. Mod., Head		27.63
" " Base		20.8
Ratio M.I. to Area		6.00
" Sec. Mod. " "		1.43
" Height to Base		1.17
" Base to Height		0.86



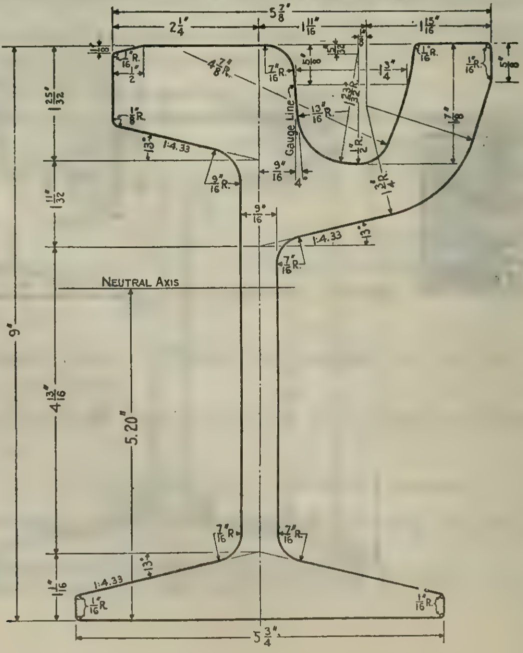
GIRDER RAIL SECTION—159-LB.—R.E.—9-A

AREA	Square Inches	Per Cent
Head	8.61	55.09
Web	2.77	17.72
Base	4.25	27.19
Total	15.63	100.00
Mom. of Inertia		164.1
Sec. Mod. Head		40.2
" " , Base		33.4
Ratio M. I. to Area		10.50
" Sec. Mod. " "		2.13
" Height to Base		1.57
" Base to Height		0.64



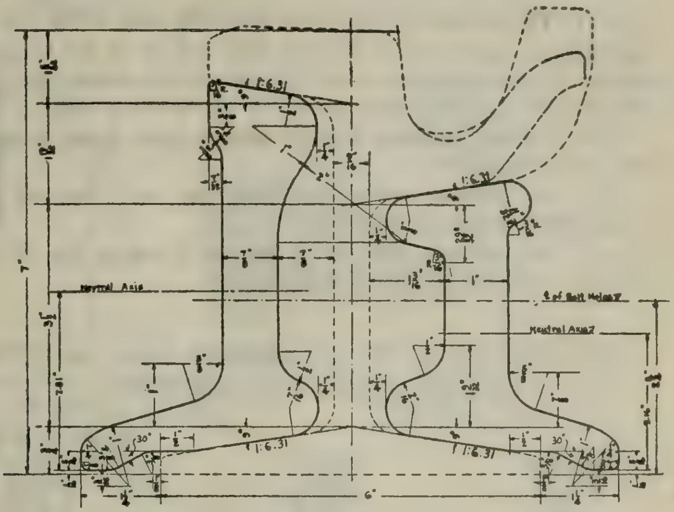
GIRDER GUARD RAIL SECTION—174-LB.—R.E.—9-A

AREA	Square Inches	Per Cent
Head	9.98	58.71
Web	2.77	16.29
Base	4.25	25.00
Total	17.00	100.00
Mom. of Inertia		180.2
Sec. Mod., Head		47.4
" " , Base		34.7
Ratio M I to Area		10.60
" Sec. Mod " "		2.04
" Height to Base		1.57
" Base to Height		0.64



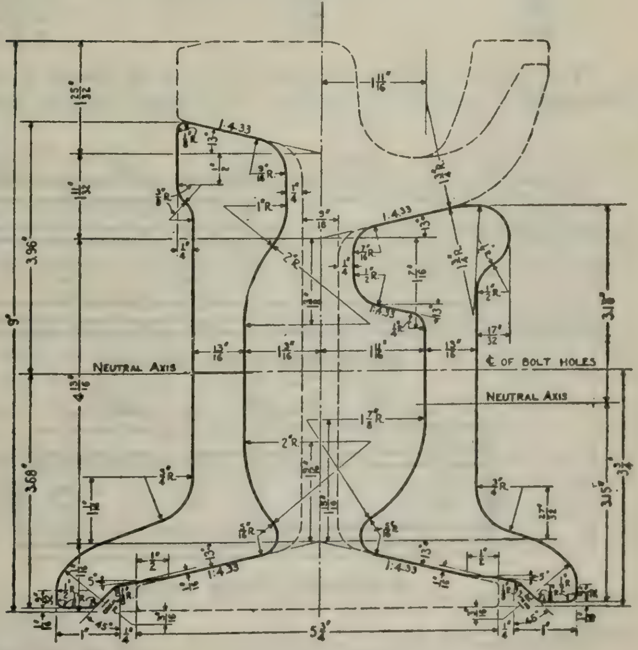
JOINT BARS—128-LB.—R.E.—7-A

AREA	Sq. Inches	
	[illegible] Bar	[illegible] Bar
Total	7.93	7.18
Mom. of Inertia	29.42	14.07
Sec. Mod. above N.A.	8.89	5.81
" " below N.A.	10.47	6.51
Wt. per Inch	2.24	2.03
Ratio M.I. to Area	3.71	1.96
" Sec. Mod. to "	1.12	.81
Joint Stiffness	128 lb.-55.8%	
	149 lb.-49.6%	



JOINT BARS—159-LB.—R.E.—9-A

AREA	Sq. Inches	
	[illegible] Bar	[illegible] Bar
Total	9.30	9.00
Mom. of Inertia	53.7	36.3
Sec. Mod. above N.A.	13.6	11.4
" " below N.A.	14.6	11.5
Wt. per Inch	2.66	2.53
Ratio M.I. to Area	5.72	4.03
" Sec. Mod. " "	1.44	1.27
Joint Stiffness	159 lb.-54.8%	
	173 lb.-49.9%	



[6]DRILLING OF RAILS

(1) The distance of bolt holes above the base of the rail should be such that the center line of the bolt holes will be in the horizontal plane midway between the intersections of the vertical center line of the rail with the planes of the fishing surfaces of the head and base.

(2) The end clearance between adjacent rails, bolted in normal position, should be ⅛ inch.

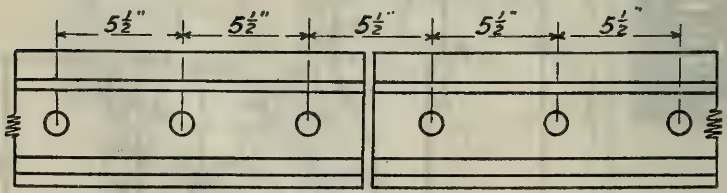
(3) For standard rails up to 120 lb. per yd., a one-inch bolt and a 1-1/16-inch bolt hole should be used.

(4) For standard rails 120 lb. per yd. to 140 lb. per yd. a 1⅛-inch bolt and 1-3/16 inch bolt hole should be used.

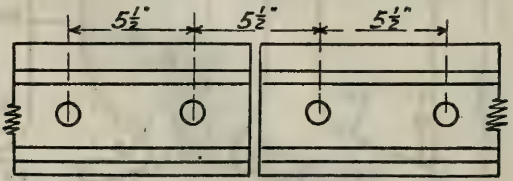
APPLICATION OF RECOMMENDED RAIL DRILLING TO STANDARD RAIL SECTIONS

Weight of Rail, Lb.	*Type of Rail*	*Height of Bolt Hole Above Base of Rail, Inches.*
90	RA-A	2 37/64
90	RA-B	2 11/32
100	RE	2 45/64
100	RA-A	2 3/4
100	RA-B	2 33/64
110	RE	2 53/64
120	RE	2 61/64
130	RE	3 1/16
140	RE	3 3/64

The standard drilling for rails should be as shown in the following diagrams:



RECOMMENDED 6-HOLE DRILLING.



RECOMMENDED 4-HOLE DRILLING.

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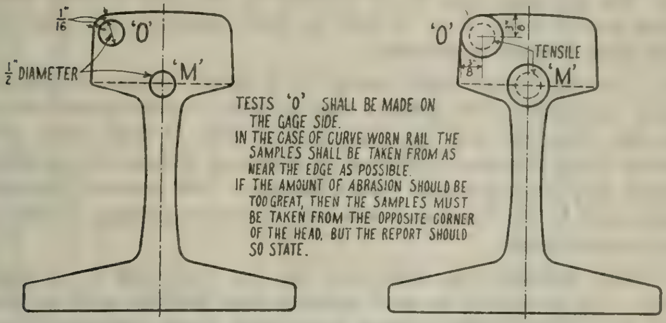
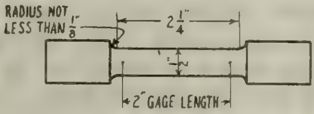
[6] Adopted, Vol. 15, 1914, pp. 157, 1110; Vol. 21, 1920, pp. 1069, 1447.

[7]STANDARD LOCATIONS OF BORING FOR CHEMICAL ANALYSES AND TENSILE TEST PIECES



TESTS 'O' SHALL BE MADE ON THE GAGE SIDE.
IN THE CASE OF CURVE WORN RAIL THE SAMPLES SHALL BE TAKEN FROM AS NEAR THE EDGE AS POSSIBLE.
IF THE AMOUNT OF ABRASION SHOULD BE TOO GREAT, THEN THE SAMPLES MUST BE TAKEN FROM THE OPPOSITE CORNER OF THE HEAD, BUT THE REPORT SHOULD SO STATE.

FOR CHEMICAL ANALYSES FOR PHYSICAL TEST PIECES



NOTE:- THE GAGE LENGTH, PARALLEL PORTIONS AND FILLETS SHALL BE AS SHOWN BUT THE ENDS MAY BE OF ANY FORM WHICH WILL FIT THE HOLDERS OF THE TESTING MACHINE.

[8]SPECIFICATIONS FOR DROP TEST MACHINE

A drop test machine conforming essentially to the manufacturers' plans and specifications and in general accord with the following requirements will give satisfactory results:

1. The machine shall be arranged to allow a 2,000-lb. tup to fall freely at least 25 feet on the center of a rail resting on supports that can be adjusted to spans varying from 3 feet to 4 feet 6 inches.

2. The anvil shall be a solid casting, weighing, with the attachments that move with it, 20,000 lb. It shall be free to move vertically independent of the lead columns. It shall be supported on 20 springs known as the standard "C" spring, without center coil, as employed by the Mechanical Division, A. R. A. (their Fig. 5614). This spring has a free length of 8¼ inches, an outside diameter of 5-7/16 inches, and is made from a bar having a diameter of 1-3/16 inches. These springs shall be arranged in groups of five at each corner of the anvil. They shall be held in place by hubs raised on the top of the base plate, and by circular pockets on the

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[7] Adopted, Vol. 12, 1911, Part 2, p. 14; Part 1, p. 470; Vol. 19, 1918, pp. 410, 1241; Vol. 28, 1927, pp. 918, 1347.

[8] Adopted, Vol. 10, Part 1, 1909, pp. 369-373, 375, 395, 396; Vol. 11, Part 1, 1910, pp. 240, 252, 562.

underside of the anvil. The anvil shall be guided in its vertical movement by removable finished wearing strips. These wearing strips shall be suitably attached to the finished edges of the column base.

3. The base-plate shall be of cast-iron or cast steel 8 inches thick in the area covered by the anvil. It shall be firmly secured to the substructure by four bolts 2 inches in diameter.

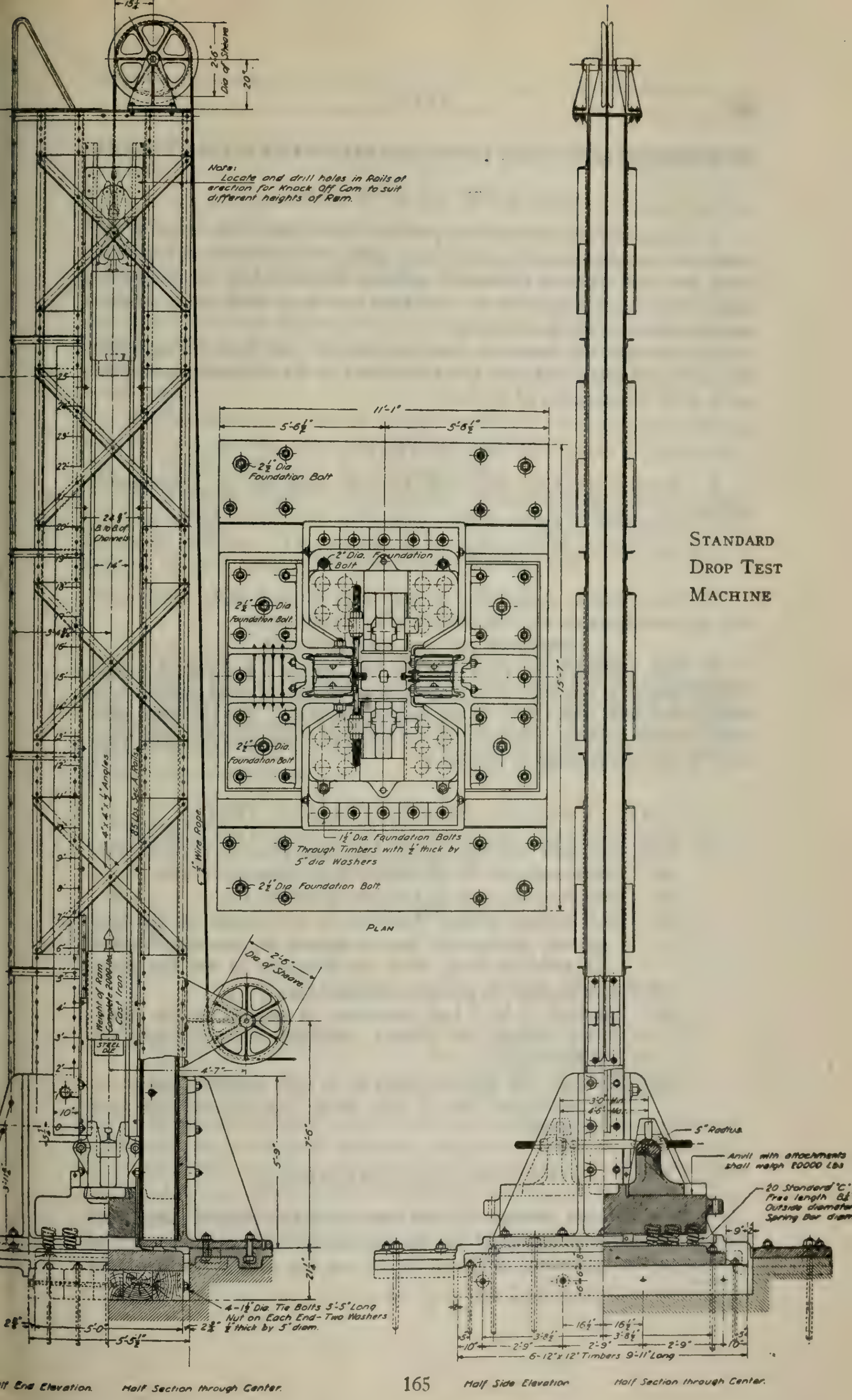
4. The substructure shall consist of a timber grillage resting on a masonry foundation. The grillage shall project 9 inches beyond the ends of the base plate, and clear the columns at the side. It shall consist of one course of 12 by 12 inches sound oak or Southern yellow pine, preferably creosoted, laid close and well bolted together. The masonry, preferably concrete, shall be not less than 5 feet deep below the grillage, suitably supported on the subsoil.

5. The pedestals for supporting the test rail shall be substantial castings. The surface of the anvil between these pedestals shall be formed to receive a wooden block to absorb shock under broken test pieces, the rail supports shall be removable pieces of steel, securely held in the pedestals, having an upper cylindrical bearing surface, with a radius of 5 inches. The pedestals shall be adjustable to spans varying from 3 feet minimum to 4 feet 6 inches maximum between centers. They shall be securely held together, and so fixed to the anvil as to insure that the center of the span shall always coincide with the center between leads.

6. The leads shall be firmly connected to the column base and well braced. They shall be long enough to provide the prescribed free fall of the tup. They shall be provided with a convenient ladder and a plainly marked gage, divided into one-foot intervals. The zero of this gage shall be 5¼ inches above the top of the rail support. The specified height of drop shall be measured from this zero irrespective of the height of the rail being tested. One of the guides shall have a removable section 6 feet long at the bottom, so that the tup or tripping block may be readily removed.

7. The tup shall weigh, with the accessories that drop with it, 2,000 lb. The striking die shall be of steel, having a cylindrical striking face, with a radius 5 inches and a length of 12 inches. The guide grooves shall have finished surfaces. The tripping head shall allow a grip of the tongs that will release at the exact height for which the tripping device is set, and that will be safe from accidental release while the test piece is being shifted.

8. The tongs and tripping device shall be arranged to release the tup automatically only. No manual releasing will be allowed. The tripping device shall be easily adjusted at one-foot intervals.


15¼"
2'-6" Dia of Sheave
20"
Note: Locate and drill holes in Rails at erection for Knock Off Cam to suit different heights of Ram.
11'-1"
5'-6½"
5'-6½"
2½" Dia Foundation Bolt
2" Dia. Foundation Bolt
2½" Dia Foundation Bolt
2½" Dia Foundation Bolt
15'-7"
1½" Dia. Foundation Bolts Through Timbers with ½" thick by 5" dia Washers
2½" Dia Foundation Bolt
PLAN
24⅝" B. to B. of Channels
14"
4"x4"x½" Angles
85 lbs Sec. A Rails
½" Wire Rope
2'-6" Dia of Sheave
Weight of Ram Complete 2000 lbs Cast Iron
STEEL DIE
4'-7"
7'-6"
5'-9"
21¼"
4-1½" Dia. Tie Bolts 5'-5" Long Nut on Each End - Two Washers ½" thick by 5" diam.
2⅜"
5'-0"
5'-5½"
2⅝"
3'-0" Min.
4'-6" Max.
5" Radius
Anvil with attachments shall weigh 20000 Lbs
20 Standard "C" Free length Outside diameter Spring Bar diam
9'-2"
16½"
16½"
3'-8½"
3'-8½"
10"
2'-9"
2'-9"
2'-9"
10"
6-12"x12" Timbers 9'-11" Long
lf End Elevation
Half Section through Center
Half Side Elevation
Half Section through Center

STANDARD
DROP TEST
MACHINE

[9]SPECIFICATIONS FOR HIGH-CARBON STEEL JOINT BARS

(I) BASIS OF PURCHASE

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the joint bars have been made in accordance with the terms of the specifications.

2. All tests and inspection shall be made at the place of manufacture prior to loading, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

(II) MATERIAL

3. Material for joint bars shall be steel, made by the Open-hearth process.

(III) CHEMICAL PROPERTIES

4. The chemical composition of each melt of steel from which joint bars are manufactured shall be within the following limits:

Phosphorus, per cent, maximum 0.04.

5. The manufacturer shall furnish the inspector a complete report of ladle analysis, showing carbon, manganese, phosphorus and sulphur content of each melt represented in the finished material. The purchaser may make a check analysis from the finished material; such analysis shall conform to the requirements of Section 4.

(IV) PHYSICAL PROPERTIES AND TESTS

6. Joint bars shall conform to the following physical requirements:
    - (a) Tensile strength, lb. per square inch, minimum, 85,000.
    - (b) Elongation, per cent in 2 inches, minimum 16.
    - (c) Cold bending without fracture on the outside of the bent portion through 90 degrees around an arc the diameter of which is three times the thickness of the test piece.
7. All test pieces shall be cut from finished bars.
    - (a) Standard ½ by 2 inch specimens, as adopted by the American Society for Testing Materials, shall be used for tension test.
    - (b) The bend test specimen shall be ½ inch square in section, or a rectangular bar ½ inch thick, with two parallel faces as rolled.

(V) GENERAL REQUIREMENTS

8. The different sections of joint bars shall be rolled to dimensions specified in drawing furnished by the purchaser. No variation will be allowed in the dimensions affecting the fit and the fishing spaces of the

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[9]Adopted, Vol. 16, 1915, pp. 403, 1119.

rail. The maximum camber on either plane shall not exceed $\frac{1}{32}$ inch in 24 inches.

9. The joint bars shall be sheared to the length prescribed by the purchaser and shall not vary therefrom by more than $\frac{1}{8}$ inch.

10. (a) All joint bars shall be punched, slotted and shaped at a temperature of not less than 1470 degrees Fahr. (800 degrees Cent.).

(b) All bolt holes shall be punched in one operation, without bulging or distorting the section, and the bars shall be slotted for spikes when required, in accordance with the drawings, the slotting being done in one operation; a variation of $\frac{1}{32}$ inch in the size and location of the holes will be allowed.

11. All joint bars must be finished smooth and true, without swelling over or under the bolt holes, and be free from flaws, seams, checks or fins, and the fishing angles must be fully maintained.

12. The manufacturer's identification symbol, kind of material, month and year rolled and number of design, shall be rolled in raised letters and figures on each bar. The number of the melt shall be plainly stenciled on each lot of joint bars.

(VI) INSPECTION

13. The joint bars from each melt shall be piled separately until tested and inspected by the purchaser's inspector. One joint bar for tension test shall be selected by the inspector for each melt represented in finished bars, or by agreement specimens for tension test may be cut from the bar as rolled. One joint bar for bend test shall be selected by the inspector for each lot of 1000 bars or less presented.

[10]SPECIFICATIONS FOR QUENCHED CARBON STEEL JOINT BARS

(I) MATERIALS

1. The steel shall be made by the Open-hearth process.

(II) CHEMICAL REQUIREMENTS

2. The steel shall conform to the following chemical composition:

Carbon	0.35 to 0.60 per cent
Manganese	Not over 0.80 per cent
Phosphorus	Not over 0.04 per cent

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. The analysis shall be made from drillings taken at least $\frac{1}{8}$ inch beneath the surface of a test ingot obtained during the pouring of each melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 2.

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[10] Adopted, Vol. 25, 1924, pp. 406, 1283.

4. An analysis may be made by the purchaser from a finished bar representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 2.

(III) PHYSICAL REQUIREMENTS

5. (a) The joint bars shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	100,000
Yield point, lb. per sq. in.	70,000
Elongation in 2 inches, per cent but in no case under 12 per cent.	$\frac{1{,}600{,}000}{\text{Ten. Str.}}$
Reduction of area, per cent but in no case under 25 per cent.	$\frac{3{,}500{,}000}{\text{Ten. Str.}}$

(b) The yield point shall be determined by the drop of the beam of the testing machine.

6. The bend test specimen specified in Section 7 shall bend cold through 90 degrees around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

7. Tension and bend test specimens shall be taken from the finished bars. Tension test specimens shall conform to the dimensions of the standard A.S.T.M. two-inch test bar. Bend test specimens may be ½ inch square in section, or rectangular in section with two parallel faces as rolled, with corners rounded in radius not over $\frac{1}{16}$ inch.

8. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 6: A piece of the finished bar shall bend cold through 45 degrees around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.

9. (a) One tension and one bend test shall be made from each melt.

(b) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(c) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 and any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

10. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot one or more times, in which case two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

(IV) DESIGN AND TOLERANCE

11. The splice bars shall be smoothly rolled, true to templet, and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and notching shall conform to the dimensions specified by the purchaser. A variation of $\frac{1}{32}$ inch from the specified size of holes, of $\frac{1}{16}$ inch from the specified location of holes, and of ⅛ inch from the specified length of splice bar, will be permitted. Bars shall be straight without camber in either plane and with outside surface of web parallel to the axis of rail.

(V) MANUFACTURE

12. The finished splice bars shall be free from injurious defects and shall have a workmanlike finish.

13. Joint bars shall be punched, slotted and shaped at a temperature of not less than 1470 degrees Fahr. (800 degrees Cent.) and subsequently quenched from a temperature of 810 degrees Cent. (1490 degrees Fahr.)

(VI) INSPECTION

14. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the splice bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the splice bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. (a) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(b) Splice bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. Samples tested in accordance with Section 4 which represent rejected splice bars shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

(VII) MARKING

17. The name or brand of the manufacturer and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars and a portion of this marking shall appear on each finished splice bar.

[11]SPECIFICATIONS FOR QUENCHED CARBON STEEL AND ALLOY STEEL TRACK BOLTS

(1) MATERIALS

1. (a) The steel for the bolts shall be made by the Open-hearth process.

(b) The steel for the nuts shall be made by either or both the following processes: Bessemer or Open-hearth.

(II) CHEMICAL REQUIREMENTS

2. The steel for the bolts shall conform to the following requirements as to chemical composition:

Carbon—Not under 0.30 per cent.
Phosphorus—Not over 0.04 per cent.

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus and sulphur. This analysis shall be made from drillings taken at least ⅛ inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the Railway Company or their representatives, and shall conform to the requirements specified in Section 2.

4. An analysis may be made by the Railway Company from a finished bolt representing each melt. The phosphorus content thus determined shall conform to that specified in Section 2.

(III) PHYSICAL REQUIREMENTS

5. (a) The bolts shall conform to the following minimum requirements as to tensile properties:

	Carbon Steel	*Alloy Steel*
Ultimate tensile strength, lb. per sq. in.	100,000	110,000
Yield point, lb. per sq. in.	75,000	85,000
Elongation in 2 in. per cent	10	12

(b) The yield point shall be determined by the drop of the beam or by the dividers, the method being optional with the inspector and at a cross-head speed not to exceed ⅛ inch per minute. The tensile strength shall be determined at a speed not to exceed 1½ inches per minute.

(c) The capacity of the nut in developing the full strength of the bolt shall be determined by a strip test. The threads must not strip when the bolt, with nut fully mounted, is tested in tension to its yield point, the load being applied to the head and the outside of the nut.

6. Full-size bolts shall bend cold through 45 degrees around a pin, the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion.

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[11] Adopted, Vol. 25, 1924, pp. 403, 1282.

7. Tension test specimens shall be taken from the finished bolts and shall conform to the dimensions of the A.S.T.M. standard test specimen. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

8. (a) One tension, one bend, and one strip test shall be made from each lot of 50 kegs or fraction thereof.

(b) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(c) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (a) and any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, or if the bend test specimen breaks in the threaded portion, a retest shall be allowed.

9. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot one or more times, in which case two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

(IV) DESIGN AND TOLERANCE

10. (a) The nominal size of rolled thread bolts shall be the over all diameter of the rolled threads.

(b) The bolts and nuts shall conform to the dimensions specified by the Railway Company, subject to the following variations: A variation of $\frac{1}{32}$ inch under and $\frac{1}{64}$ inch over the specified diameter of the shank of the bolt will be permitted. The diameter of the shank shall not be below the diameter of the rolled thread by more than $\frac{1}{16}$ inch for bolts ⅞ inch in diameter and under, nor more than $\frac{3}{32}$ inch for bolts 1 inch in diameter and over. The length of the bolt under the head shall not vary more than ⅛ inch from that specified. A variation in the dimensions of the elliptical shoulders under the head of $\frac{1}{32}$ inch will be permitted.

(V) MANUFACTURE

11. The bolts and nuts shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with and firmly jointed to the shank, with the under side at right angles to the axis of the bolt. The threads shall be sharp and true to gage and may be rolled or cut. The nuts shall have a handfree fit on the bolt from four to six turns and tight with a 15-inch wrench the balance of the screw length without distorting the threads. They shall be screwed on the bolts before packing a sufficient number of turns to hold them in place until used. The bolts shall enter the quenching medium at a temperature of not less than (790 degrees Cent.) 1450 degrees Fahr.

12. The finished bolts and nuts shall be free from injurious defects and shall have a workmanlike finish.

(VI) INSPECTION

13. The inspector representing the Railway Company shall have free entry at all times, while work on the contract of the Railway Company is being performed, to all parts of the manufacturer's works which concern the manufacture of the bolts and nuts ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bolts and nuts are being furnished in accordance with these specifications. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. (a) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(b) Bolts and nuts which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer will be notified.

15. Samples tested in accordance with Section 4 which represent rejected bolts shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make claim for a hearing within that time.

(VII) MARKING

16. (a) A letter or brand indicating the manufacturer and the initials "H T" shall be pressed on the head of the bolt when it is formed.

(b) All containers shall be marked by the manufacturer as follows:

(1) Name of manufacturer.
(2) Material (carbon or alloy steel).
(3) Size of bolts (diameter and length).
(4) Weight.

[12]DESIGN FOR TRACK BOLTS

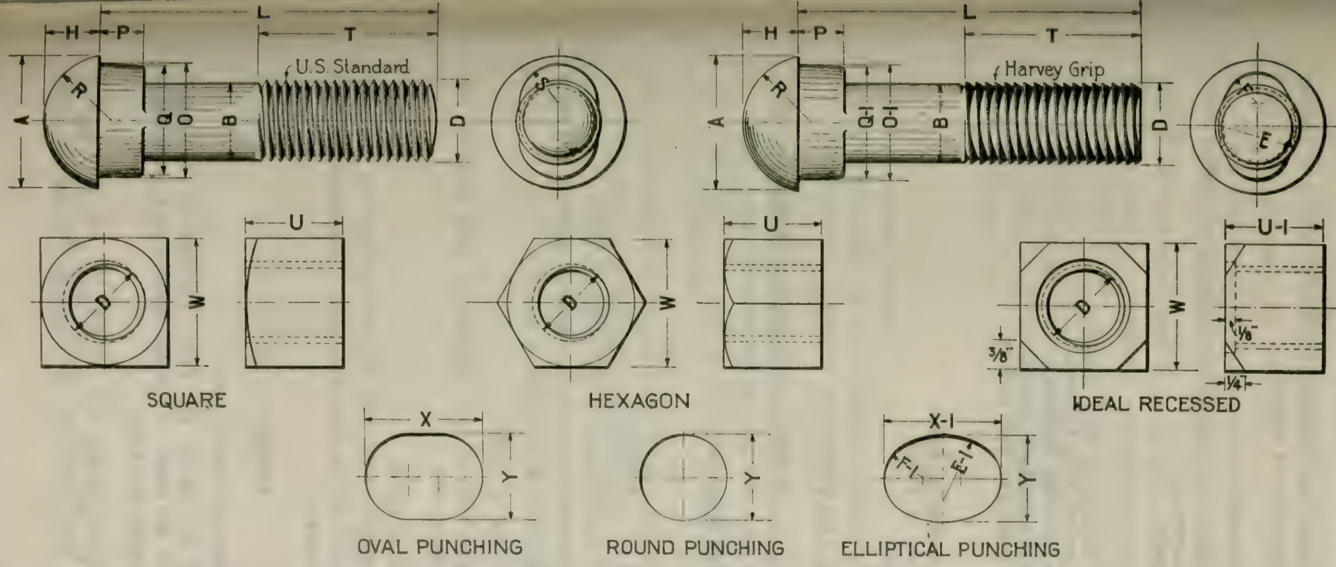

TABLE OF DIMENSIONS - INCHES

BOLT																NUT				BAR PUNCHING				
D	N	B	L	T	A	H	R	S	O	Q	P	O-1	Q-1	E	F	U	U-1		W	X	Y	X-1	E-1	F-1
Threads		Body			Head			Shoulder-Oval Type			Shoulder	Shoulder - Elliptic Type				Thickness			Width	Oval	Round	Elliptical		
Max Dia.	No per In.	Shank Dia.	Length under Hd	Length of Th'd	Dia.	Thick	Rad	Rad	Width Max	Width Min	Depth	Width Max	Width Min.	Rad Max	Rad Min	Std. Sq & Hex.	Ideal Rec.		across Flats	Length	Oval & Ellip	Length	Rad Max	Rad. Min
3/4	10	11/16	As specified Oil quenched to be 1/4" longer than Common.	1-3/4	1-1/4	15/32	21/32	11/32	1-1/16	1-1/32	7/16	1-1/16	1-1/32	21/32	7/32	1-0	1-1/8	Note When other than heat treated bolts are used, Nut to be 1/4" less in thickness	1-1/4	1-3/32	13/16	1-1/16	5/8	5/16
13/16	10	3/4		1-3/4	1-11/32	33/64	11/16	3/8	1-9/64	1-7/64	15/32	1-1/8	1-3/32	11/16	1/4	1-0	1-1/8		1-1/4	1-11/64	7/8	1-1/8	21/32	11/32
7/8	9	13/16		2-0	1-7/16	9/16	47/64	13/32	1-7/32	1-3/16	1/2	1-3/16	1-5/32	23/32	9/32	1-1/8	1-1/4		1-7/16	1-1/4	15/16	1-3/16	11/16	3/8
15/16	9	7/8		2-0	1-17/32	39/64	25/32	7/16	1-19/64	1-17/64	17/32	1-1/4	1-7/32	3/4	5/16	1-1/8	1-1/4		1-7/16	1-21/64	1-0	1-1/4	23/32	13/32
1-0	8	15/16		2-1/4	1-5/8	21/32	53/64	15/32	1-3/8	1-11/32	9/16	1-3/8	1-11/32	15/16	3/8	1-1/4	1-3/8		1-5/8	1-13/32	1-1/16	1-3/8	7/8	15/32
1-1/16	8	↑		2-1/4	1-23/32	45/64	7/8	1/2	1-29/64	1-27/64	19/32	1-7/16	1-13/32	31/32	13/32	1-1/4	1-3/8		1-5/8	1-31/64	1-1/8	1-7/16	29/32	1/2
1-1/8	7	1-1/16		2-1/2	1-13/16	3/4	59/64	17/32	1-17/32	1-1/2	5/8	1-1/2	1-15/32	1-0	7/16	1-3/8	1-1/2		1-13/16	1-9/16	1-3/16	1-1/2	15/16	17/32
1-3/16	7	1-1/8		2-1/2	1-29/32	51/64	31/32	9/16	1-39/64	1-37/64	21/32	1-9/16	1-17/32	1-1/32	15/32	1-3/8	1-1/2		1-13/16	1-41/64	1-1/4	1-9/16	31/32	9/16
1-1/4	7	1-3/16		2-1/2	2-0	27/32	1-1/64	19/32	1-11/16	1-21/32	11/16	1-5/8	1-19/32	1-1/16	1/2	1-1/2	1-5/8		2-0	1-23/32	1-5/16	1-5/8	1-0	19/32

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[12] Adopted, Vol. 26, 1925, pp. 635, 1419; Vol. 27, 1926, pp. 482, 1351.

[15]RAIL RECORD FORMS

(1) The following forms are considered essential and are recommended for keeping rail statistics and records:

Group 1—Inspection and Shipment:

401-A, Report of Chemical and Physical Examination of Rails.
401-B, Certificate of Inspection.
401-C, Report of Shipment.

Group 2—Rail Failures:

402-A, Report of Rail Failure in Main Track.
402-B, Monthly Summary of Rail Failures.
402-C, Yearly Summary of Rail Failures.
402-D, Statement of Rails in Main Tracks.
402-E, Statement of Transverse Rail Failure.

Group 3—Rail Wear:

403-A, Diagram of Location of Rails.
403-B, Diagram of Lines of Wear.
403-C, Record of Wear.

EXPLANATION OF FORMS

As will be noted above, the Rail Record forms are divided into three groups as follows:

401—Mill Inspection and Shipment.
402—Rail Failures.
403—Rail Wear.

Group 1

401-A, Report of Chemical and Physical Examination of Rails

This form gives the Inspector's reports of chemical, physical and other tests of rails on which acceptance or rejection is based.

401-B, Certificate of Inspection of Rails.

This form gives a statement of the amount of rails accepted and rejected of each class, tonnages, etc.

401-C, Report of Shipment of Rails.

This form gives the details of the rails loaded into each car for shipment. When properly checked by the receiving officer it furnishes the basis for the payment of the invoice.

Group 2

402-A, Report of Rail Failure in Main Track.

This form is intended for use by the Track Foreman to report each rail failure as it occurs in the track. It is the basic report from which monthly and annual summaries are made.

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[15] Adopted, Vol. 10, 1909, pp. 339-363, 375, 393-395; Vol. 11, Part 2, 1910, pp. 241-251, 576-579; Vol. 12, 1912, Part 1, p. 467, Part 2, p. 17; Vol. 22, 1921, pp. 202, 986; Vol. 24, 1923, pp. 97, 100, 1133; Vol. 25, 1924, pp. 391, 1282; Vol. 28, 1927, pp. 926, 1347.

402-B, Rail Failures for the Month.

This form is a monthly summary of the rail failures on a division.

402-C, Rail Failures for the Year.

This form is an annual summary of the rail failures and is used by each railway to make an annual report to the American Railway Association.

402-D, Statement of Steel Rails in Main Tracks.

This form is a statement showing the rails existing in the tracks at the end of the year.

402-E, Statement of Transverse Rail Failures.

This form is a statement of Transverse Fissure Rail Failures to be made quarterly.

Group 3

403-A, Location Diagram.

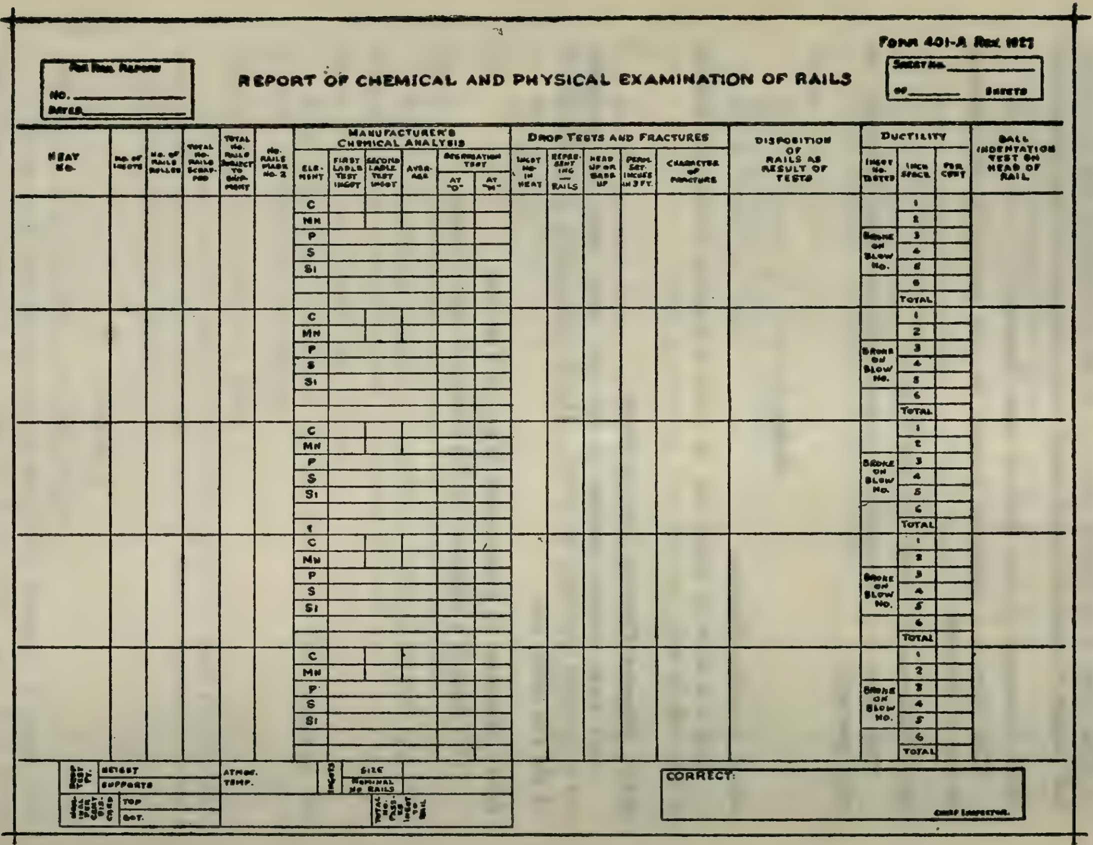
This is a form on which may be drawn a diagram showing the location of the rails in test.

403-B, Diagram Showing Lines of Wear.

This form contains sections of the rails being tested and on which the progressive wear may be shown. The diagram should be of the section of the rail under test.

403-C, Statement of Comparative Wear of Test Rail.

This form is a tabulation of the results of tests of wear.



[illegible] Report

No. ________

Dated ________

REPORT OF CHEMICAL AND PHYSICAL EXAMINATION OF RAILS

Form 401-A Rev. 1927

Sheet No. ________

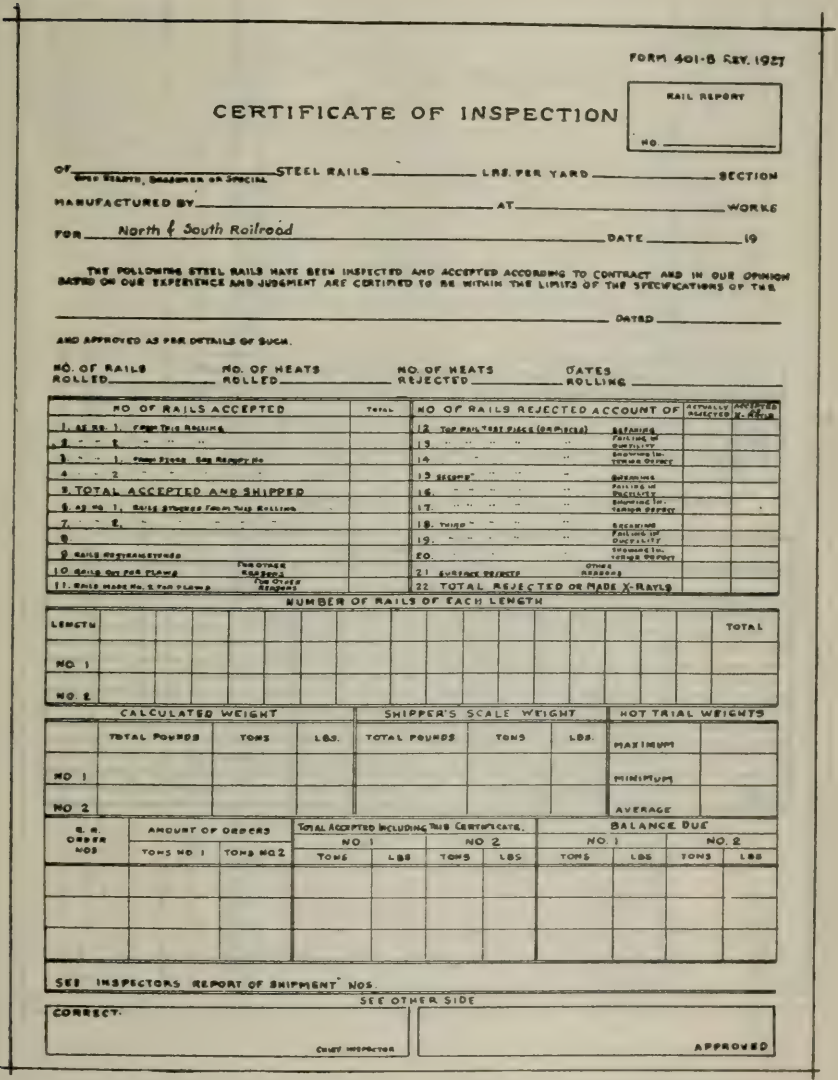
of ________ Sheets

Heat No.	No. of Ingots	No. of Rails Rolled	Total No. Rails Scrapped	Total No. Rails Subject to Shipment	No. Rails Made No. 2	Manufacturer's Chemical Analysis						Drop Tests and Fractures					Disposition of Rails as Result of Tests	Ductility			Ball Indentation Test on Head of Rail
						Element	First Ladle Test Ingot	Second Ladle Test Ingot	Average	Segregation Test At "O"	Segregation Test At "M"	Ingot No. in Heat	Representing — Rails	Head Up or Base Up	Perm. Set. Inches in 3 Ft.	Character of Fracture		Ingot No. Tested	Inch Space	Per Cent	
						C													1		
						Mn													2		
						P												Broke on Blow No.	3		
						S													4		
						Si													5		
																			6		
																			Total		
						C													1		
						Mn													2		
						P												Broke on Blow No.	3		
						S													4		
						Si													5		
																			6		
																			Total		
						C													1		
						Mn													2		
						P												Broke on Blow No.	3		
						S													4		
						Si													5		
																			6		
																			Total		
						C													1		
						Mn													2		
						P												Broke on Blow No.	3		
						S													4		
						Si													5		
																			6		
																			Total		
						C													1		
						Mn													2		
						P												Broke on Blow No.	3		
						S													4		
						Si													5		
																			6		
																			Total		

[illegible]	Height	Atmos. Temp.	[illegible]	Size	
	Supports			Nominal No. Rails	
[illegible]	Top		[illegible]		
	Bot.				

CORRECT:

Chief Inspector.



FORM 401-B REV. 1927

RAIL REPORT

NO. ________

CERTIFICATE OF INSPECTION

OF ________ (OPEN HEARTH, BESSEMER OR SPECIAL) STEEL RAILS ________ LBS. PER YARD ________ SECTION

MANUFACTURED BY ________ AT ________ WORKS

FOR North & South Railroad DATE ________ 19

THE FOLLOWING STEEL RAILS HAVE BEEN INSPECTED AND ACCEPTED ACCORDING TO CONTRACT AND IN OUR OPINION BASED ON OUR EXPERIENCE AND JUDGMENT ARE CERTIFIED TO BE WITHIN THE LIMITS OF THE SPECIFICATIONS OF THE

________ DATED ________

AND APPROVED AS PER DETAILS OF SUCH.

NO. OF RAILS ROLLED ________ NO. OF HEATS ROLLED ________ NO. OF HEATS REJECTED ________ DATES ROLLING ________

NO OF RAILS ACCEPTED	TOTAL	NO OF RAILS REJECTED ACCOUNT OF		ACTUALLY REJECTED	ACCEPTED AS X-RAILS
1. AS NO. 1. FROM THIS ROLLING		12 TOP RAIL TEST PIECE (OR PIECES)	BREAKING		
2. " " 2 " " "		13 " " " " "	FAILING IN DUCTILITY		
3. " " 1. FROM STOCK. SEE REPORT NO		14 " "	SHOWING INTERIOR DEFECT		
4 " " 2 " " " "		15 SECOND " " " "	BREAKING		
5. TOTAL ACCEPTED AND SHIPPED		16. " " " " "	FAILING IN DUCTILITY		
6. AS NO 1, RAILS STOCKED FROM THIS ROLLING		17. " " " " "	SHOWING INTERIOR DEFECT		
7. " " 2, " " " " "		18. THIRD " " " "	BREAKING		
8.		19. " " " " "	FAILING IN DUCTILITY		
9 RAILS RESTRAIGHTENED		20. " " "	SHOWING INTERIOR DEFECT		
10 RAILS CUT FOR FLAWS / FOR OTHER REASONS		21 SURFACE DEFECTS	OTHER REASONS		
11. RAILS MADE NO. 2 FOR FLAWS / FOR OTHER REASONS		22 TOTAL REJECTED OR MADE X-RAILS			

NUMBER OF RAILS OF EACH LENGTH

LENGTH																		TOTAL
NO. 1																		
NO. 2																		

	CALCULATED WEIGHT			SHIPPER'S SCALE WEIGHT			HOT TRIAL WEIGHTS	
	TOTAL POUNDS	TONS	LBS.	TOTAL POUNDS	TONS	LBS.	MAXIMUM	
NO 1							MINIMUM	
NO 2							AVERAGE	

R. R. ORDER NOS	AMOUNT OF ORDERS		TOTAL ACCEPTED INCLUDING THIS CERTIFICATE.				BALANCE DUE			
			NO 1		NO 2		NO. 1		NO. 2	
	TONS NO 1	TONS NO 2	TONS	LBS	TONS	LBS	TONS	LBS	TONS	LBS

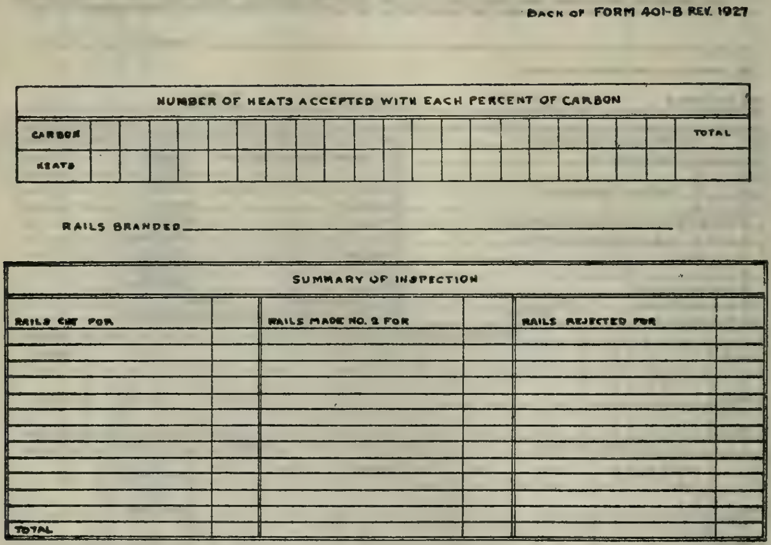
SEE INSPECTORS REPORT OF SHIPMENT NOS.

SEE OTHER SIDE

CORRECT.

CHIEF INSPECTOR

APPROVED



BACK OF FORM 401-B REV. 1927

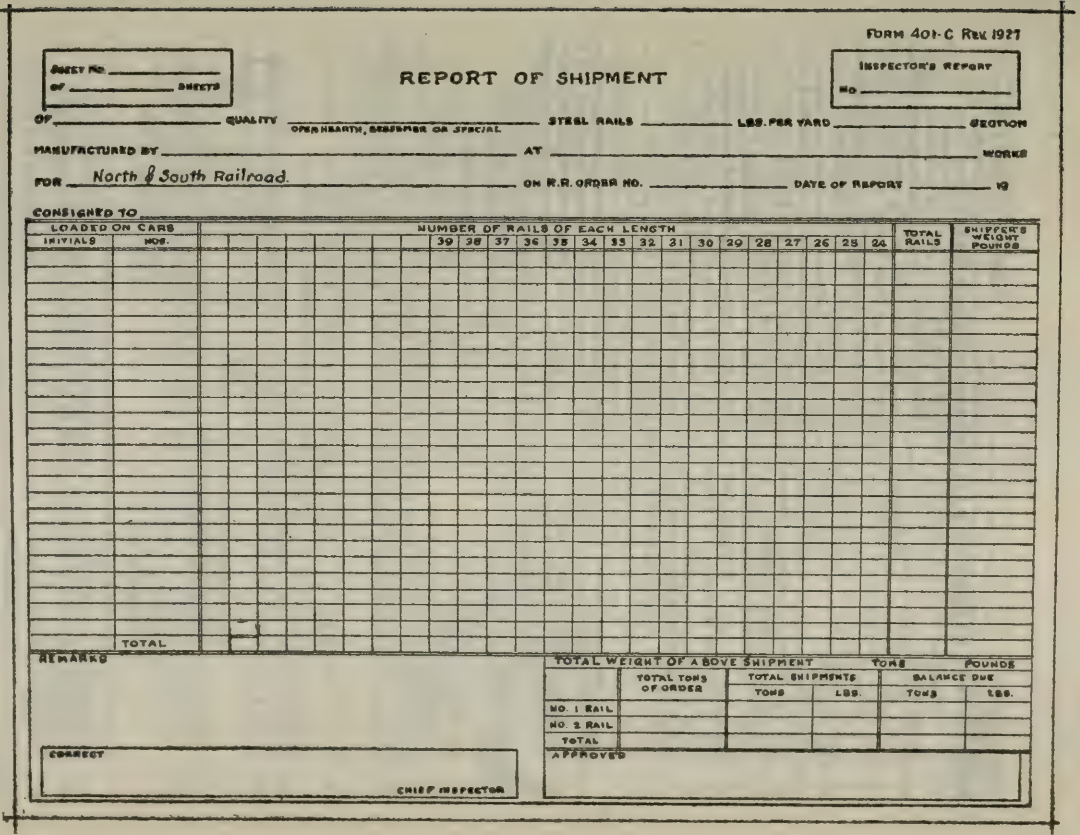
NUMBER OF HEATS ACCEPTED WITH EACH PERCENT OF CARBON

CARBON																					TOTAL
HEATS																					

RAILS BRANDED ______________________________

SUMMARY OF INSPECTION

RAILS CUT FOR		RAILS MADE NO. 2 FOR		RAILS REJECTED FOR	
TOTAL					



FORM 401-C REV. 1927

SHEET NO. ______
OF ______ SHEETS

REPORT OF SHIPMENT

INSPECTOR'S REPORT
NO. ______

OF ______ QUALITY ______ (OPEN HEARTH, BESSEMER OR SPECIAL) STEEL RAILS ______ LBS. PER YARD ______ SECTION

MANUFACTURED BY ______ AT ______ WORKS

FOR North & South Railroad. ON R.R. ORDER NO. ______ DATE OF REPORT ______ 19

CONSIGNED TO ______

LOADED ON CARS		NUMBER OF RAILS OF EACH LENGTH																								TOTAL RAILS	SHIPPER'S WEIGHT POUNDS
INITIALS	NOS.									39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24		
	TOTAL																										

REMARKS

TOTAL WEIGHT OF ABOVE SHIPMENT ______ TONS ______ POUNDS

	TOTAL TONS OF ORDER	TOTAL SHIPMENTS		BALANCE DUE	
		TONS	LBS.	TONS	LBS.
NO. 1 RAIL					
NO. 2 RAIL					
TOTAL					

CORRECT
CHIEF INSPECTOR

APPROVED

Form 402-A

Instructions and Description of Failures on Back

------------------------------Region Report No.--------

------------------------------Division,------------------------------Branch

REPORT OF RAIL FAILURE IN MAIN TRACK

Nearest to------------------------Station, State of------------------------

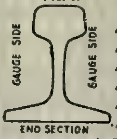
Section No.------------ Date of Report------------------------192----

1. Pounds per yard-------- 2. Rail Section-----
3. Rail Mill------------------------------
4. Date Rolled [F]------------------------------
5. Kind of Steel [G]------------------------------
6. Heat Number [H]--------- 7. Ingot No. [K]-----
8. Rail Letter [H]------------ 9. Rail Length-----
10. Was Rail—New?---Rerolled?---Resawed?---
11. Month and Year Rail was Laid--------------
12. Location [E]---feet North or West of Mile Post--
13. Which Track ?---------- 14. Which Rail?----
15. High or Low Rail of Curve----or Tangent---
16. Degree of Curve [I]------ 17. No. of Curve [I]----
18. Superelevation of High Rail at Failure--------
19. Was Rail much or little worn?--------------
20. Date and Time Found--------------------
21. Was Rail removed?---- 22. Date removed--
23. Exact Gauge of Track at Failure----------
24. Kind of Ties------------------------------
25. Were Tie Plates used?------ 26. Kind------
27. Condition of Line and Surface--------------
28. Kind of Ballast------------------------------
29. Was Track properly ballasted?--------------
30. Kind of Material in Roadbed under Ballast---
31. Was Track well drained?--------------------
32. Was Roadbed frozen?------------------------
33. Rail removed will be at------------------------
34. Describe Failure, together with Flaws or Defects, and state Cause as nearly as may be:------------

If Failure was "Broken Rail."

35. Was Break square or angular?--------------
36. Was Break over or between Ties?------------
37. Condition of Ties each side of Break----------
38. Was cause
    - Transverse Fissure?------------
    - Horizontal Fissure?------------
    - Detail Fracture?---------------
    - Sudden Rupture?---------------
39. Was Rail in track circuit?------------------
40. Was signal set to "STOP" by Break?---------
41. Indicate "Gauge Side" by crossing out repeated words on opposite side of Figs. 1. & 2.

FIG.-1.



42. Was Break outside of Joint? [J]

If Break was "in Joint," state [J]

43. Name of Joint--------------
44. Designating No. of Joint------
45. If insulated or not------------
46. No. of bolt holes------------
47. No. of bolts loose------------
48. No. of bolts missing----------
49. Sketch position and shape of Transverse Fissure on "End Section" and state size: [I-A]--------------
50. State how many additional Fissures were found in this Rail, if any, ---------- and at what distance from first one, and how located with reference to gauge side of head------------------------
51. How many rails, if any, adjacent to this one were removed because of Fissure------------------
52. Draw on diagram defects and lines of break, or partial fracture, such as long pieces from side of head, and half moon pieces from base, showing dimensions and following distances:

(a) Distance from nearest end of Rail to break or defect.

(b) Distance between edges of Ties near break.

(c) Distance from end of Rail to near edge of first Tie "Y"

(d) On double or more main tracks
- If break is nearest "Receiving End" cross out words "Leaving End."
- If nearest "Leaving End" cross out words "Receiving End."

Leaving End
Receiving End.

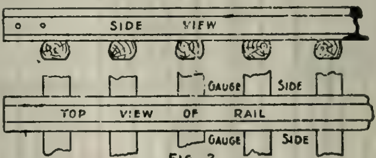


FIG.-2

53. If accident or detention to trains was caused by Break, state circumstances------------------
54. Was any passenger, employee or other person injured because of Rail Failure?------------
55. Show by "X" in square if Weather was Wet ☐ or Dry ☐ Warm ☐ or Cold ☐ Freezing ☐ or Thawing ☐
56. If "Damaged," describe nature and cause if known (report No. of train, engine or car)----------

Correct: Approved:

-------------------------------- Foreman------------------------ ---------- Supervisor

FRONT

INSTRUCTIONS

A. One of these blanks shall be filled in for each Rail which fails in a Main Track and is removed on account of being broken, defective or damaged as shown in the "Description of Rail Failures" below. Do not fill in blank for Rails which are worn out in stretches and are ready for replacement by new Rail, even though the failure may be due to flattening of the head, or other results of poor material.

B. The Foreman will send this report to the Supervisor the same day the break is found and in the case of a damaged or defective rail, the day it is taken out of the track.

C. The Supervisor will forward this report direct to the Division Engineer, who will send a copy to the Chief Engineer M. of W.

D. The term "Main Tracks" has the same meaning as in the "Book of Rules" and includes "Single Track," "Double Track" and "Three or more Tracks."

E. Mile Post number from Southeast end of Division to be used. (Question 12.)

F. The "Date Rolled" (Question 4), is shown by raised figures and lines, on the web of the Rail, the month being indicated by the number of parallel vertical lines.

G. The "Kind of Steel" (Question 5), is Bessemer "(B)"; Open Hearth "(O H)"; Nickel "(N)"; Ferro-titanium "(FT.)"; Chrome Nickel "(CN.)" or other alloy or way of making.

H. The "Heat Number" (Question 6), and the "Rail Letter" (Question 8), are stamped into the metal on the side of the web opposite to the side on which the "Brand" is rolled, figures for "6" and a letter for "8."

I. "Degree of Curve" (Question 16), and "No. of Curve" (Question 17), are given on plans or information stakes.

J. "In Joint" applies to Rail where failure starts within length covered by the joint bars.

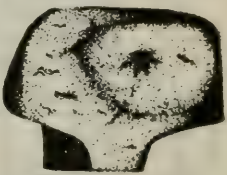
K. The "Ingot Number" is stamped on the side of the web by some makers (not yet universal)

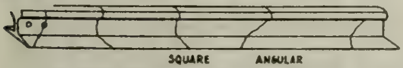
DESCRIPTION OF RAIL FAILURES

When describing Failures of Rails, the following terms should be used:

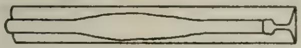
1. **BROKEN RAIL.**—(A) Transverse Fissure—A crosswise break starting from a center inside the head of the rail from which the defect spreads outward. The broken rail will show a smooth bright or dark oval spot in the head.

(B) Ordinary Break.—This term covers all partial or complete fractures (square or angular breaks) in Rails in which there is no Transverse or Horizontal Fissure, and in which none of the defects or damage described below are visible.

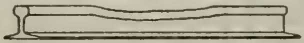

INTERNAL TRANSVERSE FISSURE



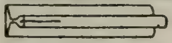
2. **FLOWED HEAD.**—This term means a "Rolling out" of the metal on top of the head toward the sides without showing any indication of a breaking down of the head structure; that is, the under side of the head is not distorted or split.

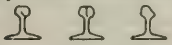


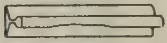
3. **CRUSHED HEAD.**—A "Flattening" of the head usually accompanied by a crushing down of the metal without any indication of a crack on the underside of the head.



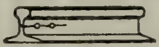
4. **SPLIT HEAD.**—This term includes Rails split along or near the middle of the head of Rails with pieces split off the side or the end of the head. When this term is used, it should be reported whether it is, or is not, accompanied by a seamed or hollowed head.

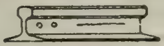


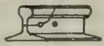


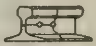


5. **SPLIT WEB.**—A longitudinal crack along the side of the web.

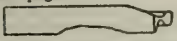


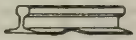






6. **BROKEN BASE.**—Any break in the base of a Rail. It should be described and sketched on the diagrams on the front page.





7. **DAMAGED.**—Under this head will be included all Rails broken or injured by wrecks, broken wheels, slipping or similar causes.

BACK

FORM 402B

North & South Railroad

RAIL FAILURES FOR THE MONTH OF..........192...ON....................DIVISION

LINE NUMBER	REPORT NUMBER	DESCRIPTION OF RAIL										LOCATION OF RAIL					DATE LAID		DAY OF MONTH FOUND	TIME IN SERVICE		NATURE OF FAILURE								IN JOINT	OUT OF JOINT
		WT. PER YARD	TYPE OF SECTION	MARKS ON RAIL							LENGTHS	MILE POST		WHICH TRACK	CURVE OR TANGENT	DEGREE OF CURVE	MO.	YEAR		YEAR	MO.	TRANS. FISSURE	BROKEN, ORDINARY	FLOWED HEAD	CRUSHED HEAD	SPLIT HEAD	CRACKED WEB	BROKEN BASE	DAMAGED		
				MANUFACTURER	ROLLED		KIND OF STEEL	HEAT NO.	INGOT NO.	RAIL LETTER		NO.	FEET																		
					MO.	YEAR																									
1																															
2																															
3																															
4																															
5																															
6																															
7																															
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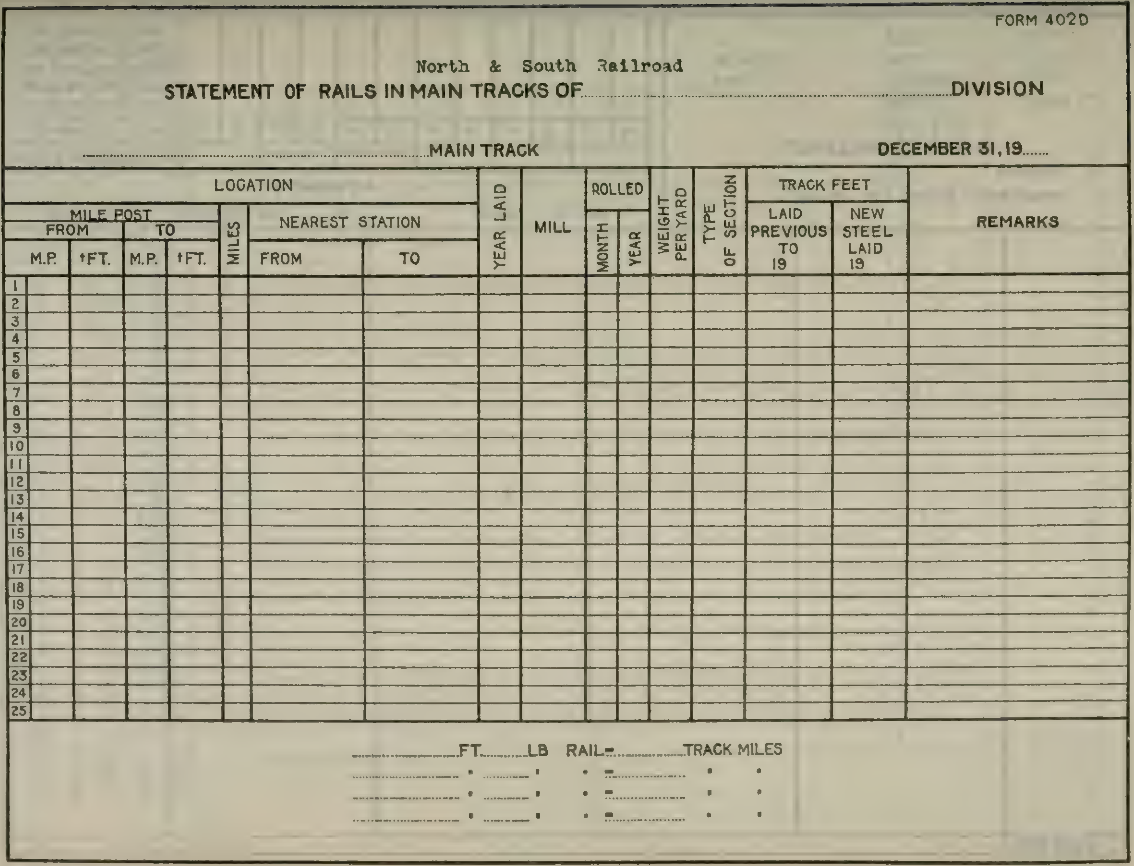
20																															
21																															
22																															
23																															
24																															
25																															
																					TOTAL FAILURES →										
																						GRAND TOTALS OF FAILURES FOR MONTH									

DATE OF STATEMENT..............192....



FORM 402D

North & South Railroad

STATEMENT OF RAILS IN MAIN TRACKS OF .... DIVISION

.... MAIN TRACK DECEMBER 31, 19......

	LOCATION							YEAR LAID	MILL	ROLLED		WEIGHT PER YARD	TYPE OF SECTION	TRACK FEET		REMARKS
	MILE POST				MILES	NEAREST STATION								LAID PREVIOUS TO 19	NEW STEEL LAID 19	
	FROM		TO													
	M.P.	†FT.	M.P.	†FT.		FROM	TO			MONTH	YEAR					
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
25																

..................FT.........LB RAIL=..............TRACK MILES
.... " .... " " =.............. " "
.... " .... " " =.............. " "
.... " .... " " =.............. " "

FORM 403A

A-..............................SHOWN IN RED B-..............................SHOWN IN YELLOW

SUMMARY

MONTH AND YEAR ⟶												
KIND OF RAIL ⟶	A	B	A	B	A	B	A	B	A	B	A	B
TOTAL SQ. IN. ABRADED. AVER. SQ. IN. ABRADED PER SEC. AREA ABRADED IN PERCENTAGE OF ORIGINAL AREA OF HEAD. TOTAL TONNAGE TO DATE.												

North & South Railroad

..............................DIVISION

LOCATION DIAGRAM

OF

..............................RAILS..............................TONS

LAID..............................REMOVED..............................

BETWEEN..............................AND..............................

DATE..............................

"TONNAGE"= TOTAL TONS (INCLUDING LOCOMOTIVES AND CABOOSE CARS) OVER EXPERIMENT FROM DATE LAID TO DATE OF REPORT, EXPRESSED IN UNITS OF 10,000 TONS.

Form 402-E

STATEMENT OF TRANSVERSE FISSURE RAIL FAILURES

From..........................19....., to..........................19.....

.... **Railway**

Date of Accompanying Report			RAIL								FAILURE				
			Process	Section	Mill	Rolled		Heat Number	Ingot No.	Letter	No.	Laid		Failed	
Mo.	Day	Year				Mo.	Year					Mo.	Year	Mo.	Year

INSTRUCTIONS FOR FILLING IN THIS FORM

1. Statements of transverse fissure rail failures on this form will be made quarterly, listing the rails that have failed during the quarters ending January 31st, April 30th, July 31st, and October 31st, each year.

2. Under "Rail" enter information from brand on rail heat and ingot numbers and rail letter.

8. Under "Failure" in column headed "No," give consecutive number this transverse fissure failure is from this heat.

5. This information will not be made public without the consent of the railroad furnishing it.

6. Include in this report all transverse fissure rail failures with as much of the information as may be available; not omitting the report nor any failure because part of the information is not available.

RAIL FAILURES FOR THE YEAR

ITEM	KIND OF STEEL	SPECIFIED CARBON		MILL	YEAR ROLLED	YEAR LAID	POUNDS PER YARD	SECTION	RAILROAD	TONS NEW RAIL LAID	EQUIVALENT TRACK MILES	MILE-YEAR	PERIOD	ITEM
		MIN.	MAX.											
1													THIS YEAR	1
													TOTAL TO DATE	
2													THIS YEAR	2
													TOTAL TO DATE	
3													THIS YEAR	3
													TOTAL TO DATE	
4													THIS YEAR	4
													TOTAL TO DATE	
5													THIS YEAR	5
													TOTAL TO DATE	
6													THIS YEAR	6
													TOTAL TO DATE	
7													THIS YEAR	7
													TOTAL TO DATE	
8													THIS YEAR	8
													TOTAL TO DATE	
9													THIS YEAR	9
													TOTAL TO DATE	
10													THIS YEAR	10
													TOTAL TO DATE	
11													THIS YEAR	11
													TOTAL TO DATE	
12													THIS YEAR	12
													TOTAL TO DATE	
13													THIS YEAR	13
													TOTAL TO DATE	
14													THIS YEAR	14
													TOTAL TO DATE	
15													THIS YEAR	15
													TOTAL TO DATE	

INSTRUCTIONS FOR FILLING IN FORM 402-C

1. Statistics are desired for all new rail weighing 70 pounds per yard and over, laid in main track of main lines and main track of branch lines. Omit rail rolled previous to 1908. Omit information for lots of less than 1,000 tons.

2. Continue records until rail disappears from main tracks where originally laid.

3. Fill in the information concerning rail lots in which there were no failures, as well as for rail lots in which there were failures.

4. Rails broken or injured by wrecks, broken wheels or similar causes, friction burned or battered end rails and those replaced on account of wear are not to be included in this report.

5. Express the tonnage of rails in whole numbers. Express the mileage in whole numbers and hundredths. Express the failures per 100 track miles in whole numbers and tenths.

6. Under "Kind of Steel" show whether the rails were Bessemer, Open-hearth or special steel.

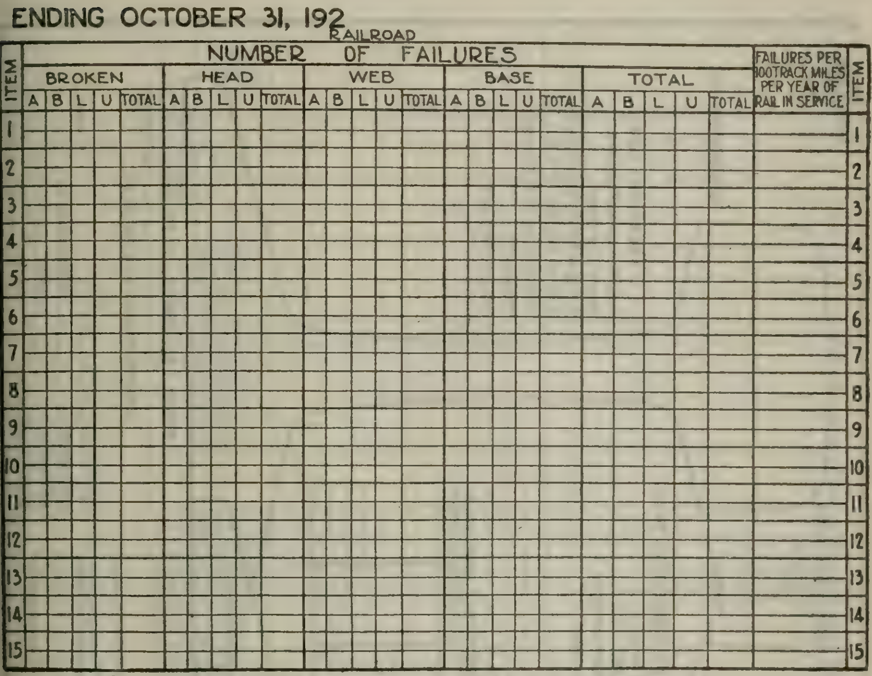
7. Under "Number of Failures" the letter "A" denotes the top rail of the ingot; "B" denotes the second rail; "L" denotes the lower rails or those below the "B" rail; "U" denotes that the ingot position of the rail is unknown.

8. To convert tons into track miles, the number of tons may be divided by the figures given below, which show the tons (2,240 lbs.) of rail per mile of single track for different weights per yard of rail.

90-lb.	141.43 tons	110-lb.	172.86 tons
91-lb.	143.00 tons	120-lb.	188.57 tons
100-lb.	157.14 tons	125-lb.	196.43 tons
101-lb.	158.71 tons	130-lb.	204.29 tons
105-lb.	165.00 tons		

9. Each line for the different rail lots should be completely filled in without the use of ditto marks. Use India ink or black typewriter ribbon and black carbon. Blueprints can thus be made and each strip formed by cutting along the horizontal lines will contain complete information for the lot it covers.

FORM 402-C
REVISED NOV. 1926.



ENDING OCTOBER 31, 192
RAILROAD

ITEM	NUMBER OF FAILURES																									FAILURES PER 100 TRACK MILES PER YEAR OF RAIL IN SERVICE	ITEM
	BROKEN					HEAD					WEB					BASE					TOTAL						
	A	B	L	U	TOTAL	A	B	L	U	TOTAL	A	B	L	U	TOTAL	A	B	L	U	TOTAL	A	B	L	U	TOTAL		
1																											1
2																											2
3																											3
4																											4
5																											5
6																											6
7																											7
8																											8
9																											9
10																											10
11																											11
12																											12
13																											13
14																											14
15																											15

10. Opposite the lines "This Year" only the failures for the year ending October 31st should be shown, and opposite the lines "Total to Date," all failures from date laid to October 31st.

11. In the column "Mile Years" there should be entered opposite the line "This Year" the actual quantity in miles of rail in service for the individual year. Opposite "Total to Date" the quantity should be the summation of miles in service for each year from date of rolling. These amounts constitute the divisors for reducing the corresponding number of failures to a 100 mile-year basis, instead of the quantity in miles originally laid, which was used as the divisor up to the year 1922.

12. For Purposes of Reporting Service of Rails:

Rail laid in any month in the year that report is made is considered to have zero years age, hence zero mile years of service.

Rail laid in any month in the year preceding the year of the report shall be considered as having one year's service.

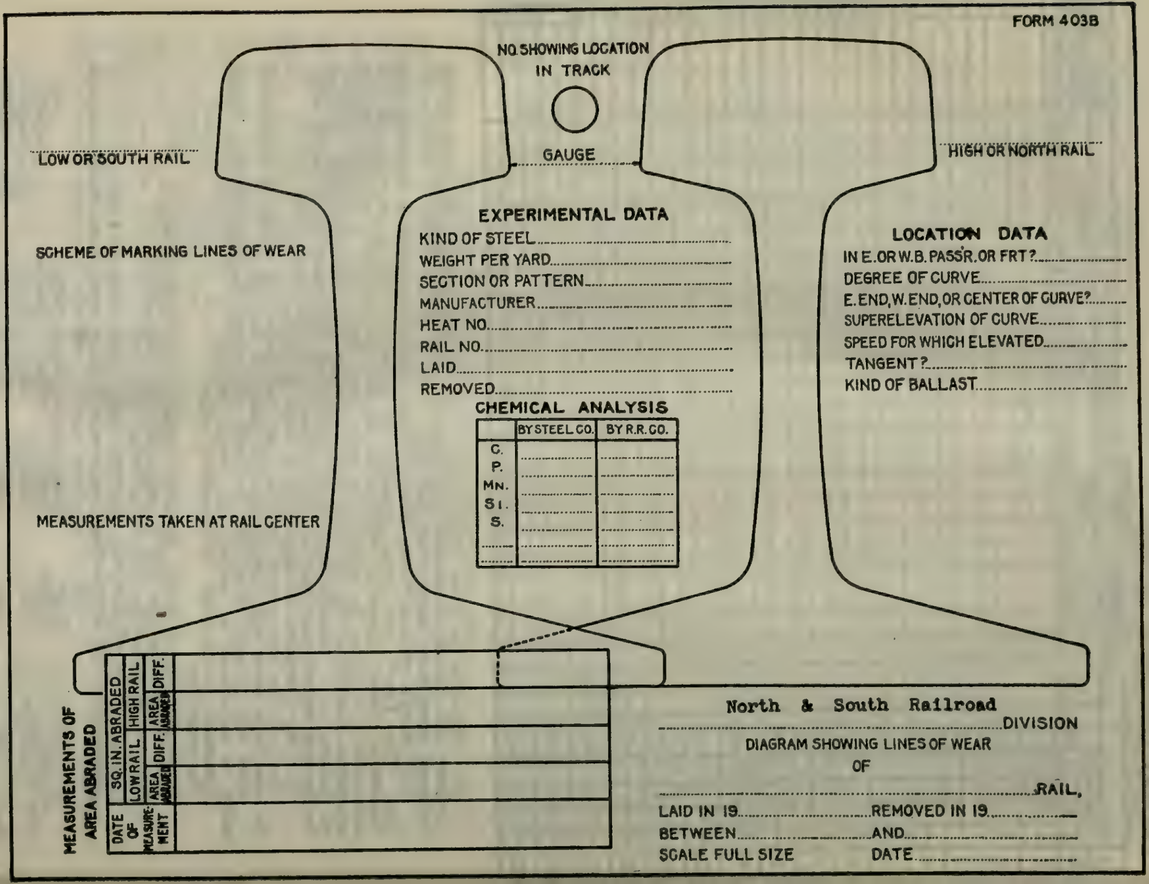
Similarly for rail laid in preceding years.

For example:

Assume 30 miles of rail rolled in calendar year 1920 of which
10 miles are laid in calendar year 1920 and
20 miles are laid in calendar year 1921.
None of this rail removed from track prior to 1923.

The reports for succeeding years would show service of these rails as follows:

Date of Report	Year Rolled	Year Laid	Equiv. Track Miles	Mile Years	Period
Oct. 31, 1920	1920	1920	10	0	This year
				0	Total to date
Oct. 31, 1921	1920	1920	10	10	This year
				10	Total to date
Oct. 31, 1921	1920	1921	20	0	This year
				0	Total to date
Oct. 31, 1922	1920	1920	10	10	This year
				20	Total to date
Oct. 31, 1922	1920	1921	20	20	This year
				20	Total to date



FORM 403B

NO. SHOWING LOCATION IN TRACK

GAUGE

"LOW OR SOUTH RAIL"

"HIGH OR NORTH RAIL"

SCHEME OF MARKING LINES OF WEAR

MEASUREMENTS TAKEN AT RAIL CENTER

EXPERIMENTAL DATA

KIND OF STEEL........................

WEIGHT PER YARD........................

SECTION OR PATTERN........................

MANUFACTURER........................

HEAT NO........................

RAIL NO........................

LAID........................

REMOVED........................

CHEMICAL ANALYSIS

	BY STEEL CO.	BY R.R. CO.
C.		
P.		
MN.		
SI.		
S.		

LOCATION DATA

IN E. OR W.B. PASS'R. OR FRT?........................

DEGREE OF CURVE........................

E. END, W. END, OR CENTER OF CURVE?........................

SUPERELEVATION OF CURVE........................

SPEED FOR WHICH ELEVATED........................

TANGENT?........................

KIND OF BALLAST........................

MEASUREMENTS OF AREA ABRADED

DATE OF MEASUREMENT	SQ. IN. ABRADED			
	LOW RAIL		HIGH RAIL	
	AREA ABRADED	DIFF.	AREA ABRADED	DIFF.

North & South Railroad

........................DIVISION

DIAGRAM SHOWING LINES OF WEAR

OF

........................RAIL,

LAID IN 19........................REMOVED IN 19........................

BETWEEN........................AND........................

SCALE FULL SIZE DATE........................

FORM 403C

North & South Railroad

STATEMENT OF COMPARATIVE WEAR OF TEST RAIL

....192......

TEST NO.	LOCATION	TAN. OR DE-GREE OF CURVE	MFR.	WT. PER YARD	TYPE OF SECTION	KIND OF STEEL	NO. OF TONS LAID	CHEMICAL COMPOSITION AVE. OF ALL HEATS							PHYSICAL PROPERTIES AVE. OF ALL RAILS TESTED				BRINELL HARDNESS NO.	DATE LAID	DATE REMOVED IF NOT STILL IN TRACK	DATE OF LAST MEASUREMENT	LGTH. OF SER-VICE AT TIME OF LAST MEAS. IN YRS.	*TONNAGE OVER RAILS	PER CENT OF AREA OF HEAD ABRADED AVE.	AREA ABRADED IN SQ. IN. AVERAGE OF ALL SECTIONS TAKEN		
								CAR.	PHOS.	MAN.	SIL.	SUL.	NI.	CHR.	TENSILE STRENGTH LBS. PER SQ. IN.	ELASTIC LIMIT LBS. PER SQ. IN.	ELONGATION % OF ORIG. LENGTH	REDUCTION OF AREA % OF ORIG. SEC.								TOTAL	PER YEAR OF SERVICE	PER 10 MILLION TONS
1																												
2																												
3																												
4																												
5																												
6																												
7																												
8																												
9																												
10																												
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26																												
27																												
28																												
29																												
30																												

*"TONNAGE"-TOTAL TONS (INCLUDES LOCOMOTIVES AND CABOOSE CARS) OVER EXPERIMENT FROM DATE LAID TO DATE REMOVED, EXPRESSED IN UNITS OF 10,000 TONS

[14]RAIL BATTER

(1) Joint battering cannot be entirely prevented but may be ameliorated. The most promising sources of such amelioration are exhaustive studies of mill conditions, track construction and maintenance.

(2) All other things being equal, evidence indicates rail battering is approximately proportional to the width of the joint gap.

(3) Effective anchorage applied at the time the rail is laid (in both directions on single track) is essential toward the proper preservation of the expansion spaces provided in the original laying of the rail.

(4) The maintenance of bolt tension adequate but not greatly exceeding that required to produce the maximum strength of the joint is essential toward the maintenance of proper expansion spaces.

(5) The reconditioning of rail ends by either electric or oxy-acetylene welding has not been found detrimental to the rail. Either method gives an adequate wearing surface to the rail ends when the metal is properly applied. It provides an economical means for restoring battered rail ends to their true surface, and is recommended as good practice.

[15]RAIL BATTER INVESTIGATIONS

Method.—For statistical purposes standard sheets should be used and the following seven readings included, as shown.

(1) Leaving rail batter length
(2) Leaving rail half inch point batter
(3) Leaving rail end batter
(4) Receiving rail end batter
(5) Receiving rail half inch point batter
(6) Receiving rail batter length
(7) Difference in end elevation.

The adoption as standard of a 24-inch straight edge with dial micrometer for taking batter measurements is recommended for two reasons:

(1) To obtain sufficient bearing on the unbattered surface of badly battered rail.

(2) To obtain a greater uniformity of results when comparing readings taken on various railroads.

Two sheets for taking batter data are given below:

(1) "A.R.E.A. Rail Batter Investigation," which completely describes the location and conditions where batter readings are to be taken.

(2) "A.R.E.A. Rail Batter Notes," which contain the actual readings. When readings are to be taken periodically, at the same location, it will only be necessary to fill in the second sheet when taking subsequent readings as the first sheet will always apply.

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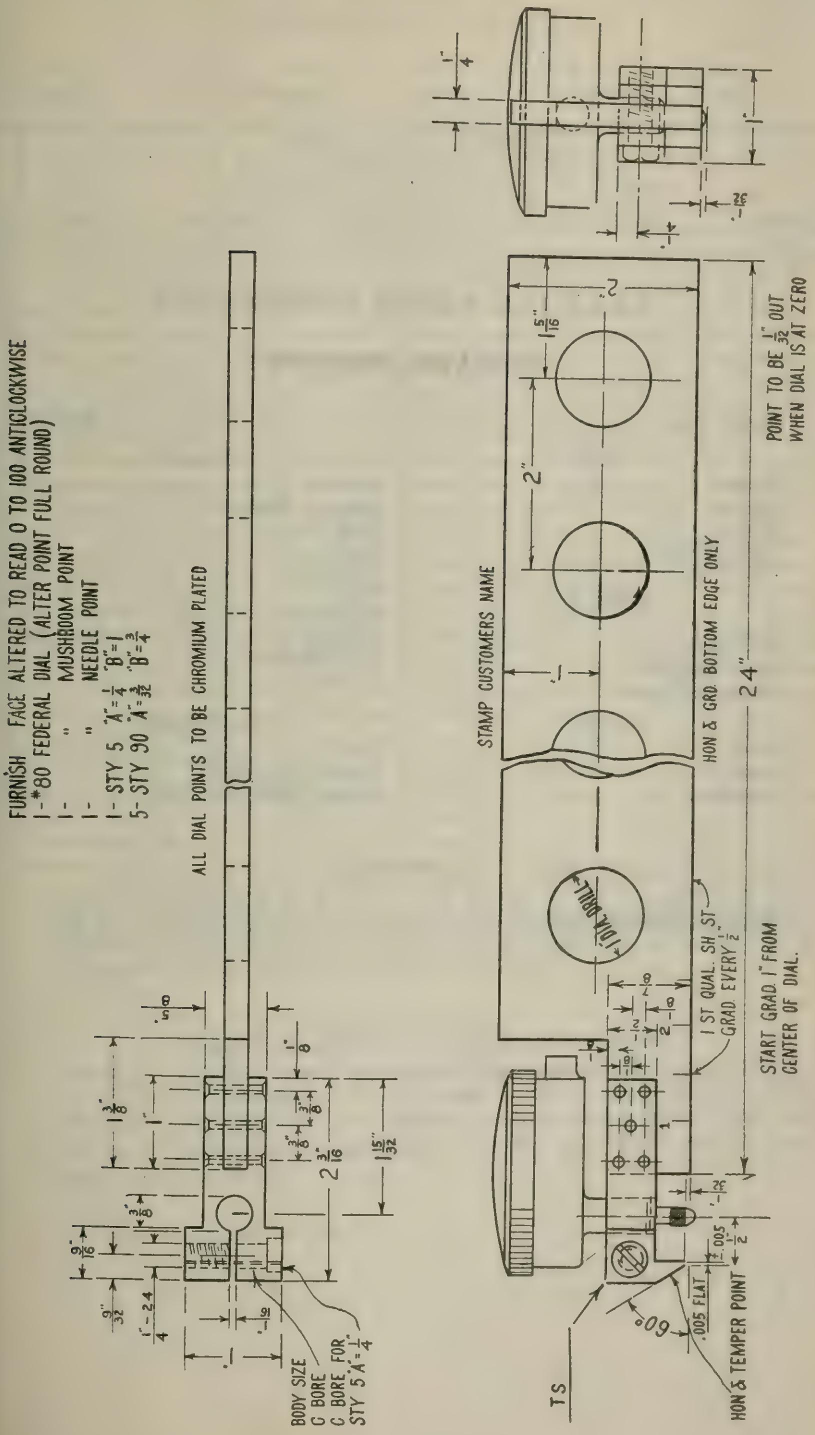
[14] Adopted, Vol. 28, 1927, pp. 980, 1340; Vol. 30, 1929, pp. 1303, 1484.
[15] Adopted, Vol. 30, 1929, pp. 1271, 1482.

RAIL BATTER GAGE


FURNISH FACE ALTERED TO READ 0 TO 100 ANTICLOCKWISE
1-*80 FEDERAL DIAL (ALTER POINT FULL ROUND)
1- " " MUSHROOM POINT
1- " " NEEDLE POINT
1- STY 5 "A"=1/4 "B"=1
5- STY 90 "A"=3/32 "B"=3/4
ALL DIAL POINTS TO BE CHROMIUM PLATED
STAMP CUSTOMERS NAME
HON & GRD. BOTTOM EDGE ONLY
POINT TO BE 1/32" OUT WHEN DIAL IS AT ZERO
1 ST QUAL. SH. ST.
GRAD. EVERY 1/2"
START GRAD. 1" FROM CENTER OF DIAL.
1/4 DIA. DRILL
HON & TEMPER POINT
.005 FLAT
60°
±.005
TS
BODY SIZE
C BORE
C BORE FOR STY 5 "A"=1/4"
24"
2"
2"
1 5/16
1"
1"
1/4"
1/4
1/32
1/32
2 3/16
1 15/32
1 3/8"
3/8
3/8"
3/8"
1/8"
3/8"
9/16"
9/32
1"-24
1/16
1
1/2
1/8
7/8
2 1/8

A.R.E.A. RAIL BATTER INVESTIGATION

Track Under Observation

Initial Date .... Railway

Rail

Weight ....
Section ....
Mfgr. ....
Date rolled ....
Date Laid ....

Splice Bar

Type ....
No. Holes ....
Date Applied ....
Previous Type ....

Ballast

Kind ....
Depth ....
Condition ....

General

Division ....
Nearest Station ....
Mile Post ....
Track ....
Curvature ....
Grade ....
Alinement ....
Tonnage ....Per Year
Superelevation ....
Surface ....

Anti-Creepers

Type ....
Number per Rail..........................
Spring Washers—Type ....

REMARKS

Type of Bolt and Nut..

....

....

....

A.R.E.A. RAIL BATTER NOTES

.................................R. R.

DATE..................WEATHER..........TEMP..............SHEET........OF.................

			(EAST) LEAVING RAIL			(WEST) RECEIVING RAIL				
			BATTER			BATTER				
Jt. No.	Neat No.	Gap	Lgth.	½ in.	End	End	½ in.	Lgth	Diff. in End Elevat'n	Remarks
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
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28										
29										
30										

Joints numbered in the direction of traffic—odd numbered joints in the south or west rail. Gap in 64ths of an inch. Batter in 0.001 of an inch. Length of batter not to include secondary batter or uneveness of the rail surface. Diff. in end elevation to be measured beyond end of low rail batter—minimum of 3″ from end of rail. Receiving rail high distinguished by "R" preceding amount; diff. to be measured by placing gage on high rail with dial extended over low rail.

[16]APPLICATION OF WELDED BONDS

(1) The application of welded bonds to the outside of the rail within the limits of the joint bars for standard bonding and outside of joint bars for special work where not practicable to apply them within the joint bar limits, is good practice.

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[16] Adopted, Vol. 28, 1927, pp. 919, 1346.

COMMITTEE V

TRACK

[1]DEFINITIONS

(See also Appendix C, pages 1, 2 and 3 in "Portfolio of Trackwork Plans.")

GENERAL TERMS

Alinement.—The horizontal location of a railway with reference to curves and tangents.

Branch Line.—The secondary line or lines of a railway.

Curve, Simple.—A curved track forming an arc of a circle of a single radius.

Curve, Degree of.—The angle subtended at the center of a simple curve by a 100-foot chord.

Curve, Compound.—A continuous change in direction of alinement by means of two or more contiguous simple curves of different degrees having a common direction at their junction points.

Curve, Easement.—A curve whose degree varies either uniformly or in some definitely determined manner so as to give a gradual transition between a tangent and a simple curve, which it connects, or between two simple curves.

Curve, Reverse.—Two contiguous simple curves in opposite directions, with a common direction at their junction point.

Curve, Vertical.—A vertical bend in the track to connect intersecting grade lines.

Connecting Track.—Two turnouts with the track between the frogs arranged to form a continuous passage between one track and another intersecting or oblique track or another remote parallel track.

Crossover.—Two turnouts with the track between the frogs arranged to form a continuous passage between two nearby and generally parallel tracks.

Crossover, Double.—A combination of two crossovers in opposite directions, which intersect between the parallel tracks.

Crossing (Track).—A device used where two tracks intersect at grade to permit the traffic on either track to run across the other and comprising four connected frogs, one for each rail intersection. See Frog. (For details, see "Crossing Terms.")

Elevation (of Curves).—The vertical distance that the outer rail is raised above the inner rail, sometimes called Superelevation.

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[1] Adopted, Vol. 5, 1904, pp. 527, 535, 541-560; Vol. 6, 1905, pp. 748, 749, 759-761; Vol. 10, Part 1, 1909, pp. 400, 461-463; Vol. 11, Part 2, 1910, pp. 942, 955; Vol. 16, 1915, pp. 728, 1144; Vol. 17, 1916, pp. 387, 905; Vol. 18, 1917, pp. 417, 1491; Vol. 25, 1924, pp. 441, 1299.

FASTENINGS.—Splice Bars, Bolts and Spikes.

FASTENINGS, AUXILIARY.—Nutlocks, tieplates, rail braces and anti-creeping devices.

FLANGEWAY.—The space between the running rail and a guard rail which provides clearance for the passage of wheel flanges.

FLANGEWAY DEPTH.—The vertical distance from the top of the running surface of the running rail to the top of a filler or separator introduced between the running rail and guard rail. A minimum depth has been standardized at 1⅞ inches.

FLANGEWAY WIDTH.—The distance between the gage line of the running track rail and the guard line of the adjacent guard rail. The standard flangeway width on straight track is 1¾ inches.

FLARE.—A tapered widening of the flangeway formed by beveling or bending the end of a guard rail or frog wing away from the gage line.

FLARE OPENING.—The horizontal distance between the gage line of the running rail and the side of the head of the guard rail or frog wing rail at the point of maximum opening.

FOOT GUARD.—A filler, preferably of metal, designed to fill spaces between converging rails to prevent the feet of persons becoming accidently wedged between the rails.

FROG.—A device used where two running rails intersect and providing flangeways to permit wheels and wheel flanges on either rail to cross the other. (For details, see "Frog Terms.")

FROG GUARD RAIL.—A rail or other device to guide the wheel flange so that it is kept clear of the point of the frog.

GAGE (a Tool).—A tool by which the gage of track is determined.

GAGE (of Track).—The distance between the heads of the rails measured at right angles thereto at a point ⅝ inch below the top of the rail.

GAGE, STANDARD.—The gage of 4 feet 8½ inches.

GAGE LINE.—A line ⅝ inch below the running surface of a rail on the side of the head nearest the center of track.

GUARD LINE.—A line on a guard rail which is on the side of the head adjacent to the running rail and on the same level as the gage line.

GUARD RAIL.—A rail laid parallel to the running rails of a track to prevent wheels from being derailed, or to hold the wheels in proper alinement to the track to prevent their flanges from striking the points of switches, or the points of frogs in turnouts or crossings. (For details, see "Guard Rail Terms.")

A rail laid parallel to the running rails of a track to keep derailed wheels on the ties.

INSULATION.—A device or material that prevents the flow of electric current in a track circuit from passing from one rail to the other or through switches and other track structures.

JOINT BAR.—A metal angle bar or other shape used in a rail joint and fitting into the sides between head and base of the abutting rails.

JOINT (Rail).—A fastening designed to unite the abutting ends of contiguous rails.

JOINT, INSULATED.—A rail joint designed to arrest the flow of the electric current from rail to rail by means of insulations so placed as to separate the rail ends and other metal parts connecting them.

Level.—The condition of the track in which the elevation of the rails transversely is equal.

Line.—The condition of the track in regard to uniformity in direction over short distances on tangents, or uniformity in variation in direction over short distances on curves.

Lining Track.—Shifting the track laterally to conform to the established alinement.

Main Line.—The principal line or lines of a railway.

Main Track.—The running track of a railway whereon the movement of trains is controlled by timetable, train order or block signal. For multiple main track generally the southerly or easterly main track shall be designated as the first main track and the adjacent one as the second main track, etc.

Out of Face (Referring to Track Work).—Work that proceeds completely and continuously over a given piece of track as distinguished from work at disconnected points only.

Scissors Crossover.—See Crossover, Double.

Slip Switch, Single.—A combination of a crossing with one right-hand and one left-hand switch and curve between them within the limits of the crossing and connecting the two intersecting tracks without the use of separate turnout frogs.

Slip Switch, Double.—A combination of a crossing with two right-hand and two left-hand switches and curves between them within the limits of the crossing and connecting the two intersecting tracks on both sides of the crossing and without the use of separate turnout frogs.

Spiral (When used with respect to Track).—A form of easement curve in which the change of degree of curve is uniform throughout its length.

Spiral, Ten Chord.—An approximate spiral measured in ten equal chords and whose change of degree of curve is directly proportional to the length measured along the spiral by such chords.

Splice Drilling.—The spacing of holes in the ends of rails or other track structures to receive the bolts for the fastening of joint bars.

Split Switch.—A device consisting essentially of two tapered movable rails with necessary connections, designed to divert rolling stock from one track to another. (For details, see "Switch Terms.")

Spur.—A line of railway diverging from a main or branch line, and over which no regular train service is maintained.

Surface (When used with respect to Track).—The condition of the track as to vertical evenness or smoothness over short distances.

Surface, Running (Tread).—The top part of track structures on which the treads of the wheels bear.

Switch.—A device consisting of two movable rails, necessary connections and operating parts, designed to turn an engine or train from a track on which it is running to another track.

Tangent.—Any straight portion of a railway alinement.

Track.—Ties, Rails and Fastenings; with all parts in their proper relative positions.

Track Bolt.—A bolt with a button head and oval neck and a threaded nut designed to fasten together rails and splice bars and other rail joint fastenings.

Turnout.—A track arrangement consisting of a switch and frog with connecting and operating parts, and extending from the point of the switch to the heel of the frog, by means of which engines and cars may pass from one track to another. (For details, see "Turnout Terms," "Switch Terms" and "Frog Terms.")

Wye.—A principal track and two connecting tracks arranged like the letter "Y," with the top closed, by means of which engines and trains may be turned.

SPLIT SWITCH TERMS

Split Switch with Graduated Risers.—A split switch in which the switch rails are gradually elevated by means of graduated riser plates until they reach the required height above the stock rail. (For names of detail parts, see Plan 191.)

Split Switch with Uniform Risers.—A split switch in which the switch rails have a uniform elevation on riser plates for the entire length of the switch. (For names of detail parts, see Plan 190.)

Manganese Tipped Switch.—A split switch in which the head of the tapered rails is cut away in the point portion and manganese steel pieces fastened to the rail to form the point.

Switch Rail or Point Rail.—The tapered rail of a split switch.

Point Rail Rise.—The elevation of a switch point rail to allow the overhanging part of hollowed out treads of worn wheels to pass over the stock rail.

Heel Slope.—The inclination produced in that part of the switch by graduated risers, which reduce the elevation (as the height of the risers decrease) toward the heel of the switch.

Bottom Planing.—The cut planed at an angle on the bottom of the base of the switch rail from the point and towards the heel to allow the switch rail to rest on the top of the base of the stock rail when the switch rail is closed.

Side Planing.—The cuts made on the sides of the head of the switch rail to form the taper from the full width of head to the point.

Top Planing.—The cut made on the top of the head of the switch rail from the point and to approximately the head separation.

Chamfer Cut.—The vertical beveling of the gage side of the switch point to produce a sharp edge to prevent wheel flanges striking the switch point.

Head Separation.—The point in a tapered switch rail where the head of the rail assumes its full width.

Point of Switch (Actual).—The point where the spread between the gage lines of the main track and the turnout is sufficient to allow for a practical switch point. (The standard width of switch point is ¼ inch.)

Vertex or Theoretical Point of Switch.—The point where the gage line of the switch rail, if produced, would intersect the gage line of the stock rail.

Stock Rail.—A running rail against which the switch rail operates.

Stock Rail Bend.—The bend or set which must be given the stock rail at the vertex of a switch to allow it to follow the gage line of the turnout.

Heel of Switch.—The end of a switch rail farther from the point of switch.

Heel Spread.—The distance between gage lines at the heel of the switch rails. This has been standardized at 6¼ inches.

Switch Angle.—The angle included between the gage lines of the switch rail and the stock rail.

Switch Fixtures.—The connecting and bearing parts for the rails of a split switch. (For details and names of parts, see Plans 201, 202, 203 and 204.)

Insulated Switch.—A switch in which the fixtures connecting or reaching from one rail to the opposite rail are provided with insulation so that an electric track circuit cannot pass through them.

Detector Bar.—A strip of metal mounted alongside the track rail and connected with the throwing mechanism of the switch to prevent the moving of the switch under trains.

Throw of Switch.—The distance through which the point of switch rails is moved sidewise, measured along the center line of the rod nearest the point connecting the two switch rails, to bring either point against the stock rail. This distance is standardized at 4¾ inches.

FROG TERMS

Bolted Rigid Frog.—A frog built entirely of rolled rails, fillers between the rails and rigidly held together with bolts. (For names of detail parts, see Plan 390.)

Clamp Frog.—A frog built of rolled rails, fillers between the rails, and held together with clamps. (For names of detail parts, see Plan 391.)

Spring Rail Frog.—A frog having a movable wing rail held against the point rail by springs, normally presenting an unbroken running surface to wheels using one track while the flanges of wheels on the other track force the wing rail away from the point rail to provide opening. (For names of detail parts, see Plan 490.)

Spring Rail Frog, Right Hand and Left Hand.—Standing at the toe end of the frog and looking towards the point, the right-hand spring frog has the spring wing rail located on the right-hand side, and the left-hand spring rail frog has it located on the left-hand side.

Railbound Manganese Steel Frog.—A frog consisting of a manganese steel center casting fitting into and surrounded by rolled rails and rigidly held together with bolts. (For names of detail parts, see Plan 690.)

Solid Manganese Steel Frog.—A complete frog cast entirely of manganese steel. (For names of detail parts, see Plan 691.)

Self-Guarded Frog (Flange Frog).—A frog provided with a guard member for guiding the flange of a passing wheel past the point of the frog by engaging the tread rim of the wheel in a horizontal plane above the top of running surface of the frog.

Frog Angle.—The angle formed by the intersecting gage lines of a frog.

Frog Number.—One-half the cotangent of one-half the frog angle, or the number of units of center line length in which the spread is one unit.

Heel End of Frog.—The end of a frog farthest from the switch and where the running surfaces, diverging from the point, terminate.

Toe End of Frog.—The end of a frog in front of the point and towards the switch.

Heel Spread.—The distance between the gage lines at the heel end of the frog.

Toe Spread.—The distance between the gage lines at the toe end of the frog.

Throat of Frog.—The point at which the converging wings of a frog are closest together.

Frog Point.—The part of a frog lying between the gage lines extending from their intersection to the heel end.

Point of Frog—

Theoretical.—The point of intersection of gage lines of the frog.

Half-Inch Point.—A point located at a distance from the theoretical point towards the heel and equal in inches to one-half the frog number and at which the spread between the gage lines is one-half inch. It is the origin from which shop measurements are made.

Actual Point.—A point at which the spread between the gage lines is sufficient to allow for a practical width of manufactured point.

Guard Point.—The point formed by guards introduced or extended into the toe portion of a frog.

Heel Length.—The distance between the heel end and the half-inch point of a frog, measured along the gage line.

Toe Length.—The distance between the toe end and the half-inch point of a frog, measured along the gage lines.

GUARD RAIL TERMS

Guard Rail (Turnout).—A rail or other device laid parallel to the running rail opposite a frog, to form a flangeway with the rail and hold wheels of equipment to the proper alinement when passing through the frog. (For names of detail parts of guard rails, see Plan 590.)

Guard Rail (Switch).—A rail or other device laid parallel to the running rail ahead of a split switch and forming a flangeway with the rail to hold wheels of equipment in proper alinement when approaching a closed switch point.

Guard Rail Brace.—A metal shape to fit the contour of the side of the guard rail and extending over the ties and fastened thereto to prevent moving or tilting of the guard rail away from the running rail.

Guard Rail Brace, Adjustable.—A guard rail brace moving on a tie plate, without disturbing the tie plate and securable thereto, to vary the distance between the guard rail and the running rail.

Guard Rail Clamp.—A device consisting of a yoke and fastening devices engaging the running rail and guard rail to hold them rigidly in relation to each other.

Adjustable Separator.—A metal block of two or more parts acting as a filler between the running rail and the guard rail and so designed as to provide varying width of flangeway.

CROSSING TERMS

Bolted Rail Crossing.—A crossing in which all running surfaces are of rolled rail and the parts are held together with bolts.

Manganese Steel Insert Crossing.—A crossing in which a manganese casting is inserted into the intersections, fitting into the rolled rails and forming the points and wings of the crossing frogs.

Solid Manganese Steel Crossing.—A crossing in which the frogs consist entirely of manganese steel castings.

Center Frogs.—The two frogs at opposite ends of the short diagonal of a crossing.

End Frogs.—The two frogs at opposite ends of the long diagonal of a crossing.

Running Rail.—The rail or surface on which the tread of the wheel bears.

Guard Rail.—The rail placed parallel with the running rail with the flangeway between them.

Easer Rail (Easer).—A rail placed with its head along the outside and close up to the head of the running rail and sloped at the ends to provide a bearing for the overhanging portion of hollowed-out treads of worn wheels.

Single Rail Crossing.—A crossing in which the connection between the end frogs and center frogs consist of running rails only.

Two-Rail Crossing.—A crossing in which the connection between end frogs and center frogs comprises running rails and guard rails.

Three-Rail Crossing.—A crossing in which the connection between end frogs and center frogs comprises running rails, guard rails and easer rails.

Movable Point Crossing.—A crossing in which each of the two center frogs is formed of an obtuse point or knuckle rail and two opposed movable tapered rails, with operating mechanism connecting them so that when two of the movable rails lie against the point or knuckle rails, giving a continuous running surface on one track, the other two stand away from the point to give clearance for the wheel flanges to pass. (Used in small angle crossings and slip switches.)

Knuckle Rail.—A bent rail forming the obtuse point against which the movable rails operate in a movable point crossing.

Movable Center Point.—The movable tapered rail in a movable point crossing.

Reinforcing Rail.—A piece of rail placed along the outside of the head of the knuckle rail or movable center point for strengthening and to act as an easer rail.

TURNOUT TERMS

Lead (Theoretical).—The distance from the theoretical point of a uniform turnout curve to the theoretical point of the frog, measured on the line of the parent track.

Lead (Actual).—The length between the actual point of the switch and the half-inch point of the frog measured on the line of the parent track.

Lead Curve.—The curve in the turnout interposed between the heel of the switch and the frog.

Curved Lead.—The length measured on the outside gage line of turnout from the point of switch to the point of frog.

Closure Rails (Lead Rails).—The rails connecting the heels of the switch rails with the toe end of the frog.

Turnout Number.—The number corresponding to the frog number of the frog used in the turnout.

[2]MAINTENANCE OF LINE

(a) Tangents

Tangents should be adjusted between summits and between curves; or by throwing curves to meet tangents; or by partially throwing curves and partially throwing tangents as may require the least work. Centers should be set with transit to secure accurate line.

(b) Curves; Use of Easement Curves

Easement curves should be used with all curves requiring an elevation of 2 inches or more for the highest permissible speed.

The choice of easement curves should be governed by the ultimate speed possibilities, considering probable revision of the worst features of alinement, rather than by existing schedule speed.

With curves of 6 degrees and over, which are speed-limiting curves, easement curves should be not less than 240 feet long.

With speed-limiting curves of less than 6 degrees, easement curves should have length in feet of not less than 5⅓ times the speed in miles per hour calculated for an elevation of 8 inches.

With curves which are not likely to limit speed, easement curves should have lengths in feet of not less than thirty times the elevation in inches for the ultimate speed, nor less than two-thirds the ultimate speed in miles per hour times the elevation in inches.

Longer easement curves than the minimum lengths thus determined may be used to advantage and will be convenient sometimes, but any considerable increase in length is wholly unnecessary and should never be made without careful consideration of the effect on cost. For minor curves an increase in length of about 50 per cent over the minimum is recommended when such increase will not seriously affect the cost nor adversely affect the degree of curve. The minimum lengths should be used in all cases where greater lengths would adversely affect the degrees of main curves.

Curve elevations should be attained and run out uniformly over the full length of easement curves with no elevation on tangents and full elevation on circular curves.

Easement curves should be used between curves of different degrees, and change of elevation should be effected just as between curves and tangents.

Any form of easement curve is satisfactory:

(1) In which the rate of increase in degree of curve can readily be changed to suit particular cases so that the length of easement curve shall be the same as the distance in which the outer rail is raised from nothing to full elevation.

(2) Which can be run in by deflection or offset with chords of any desired length.

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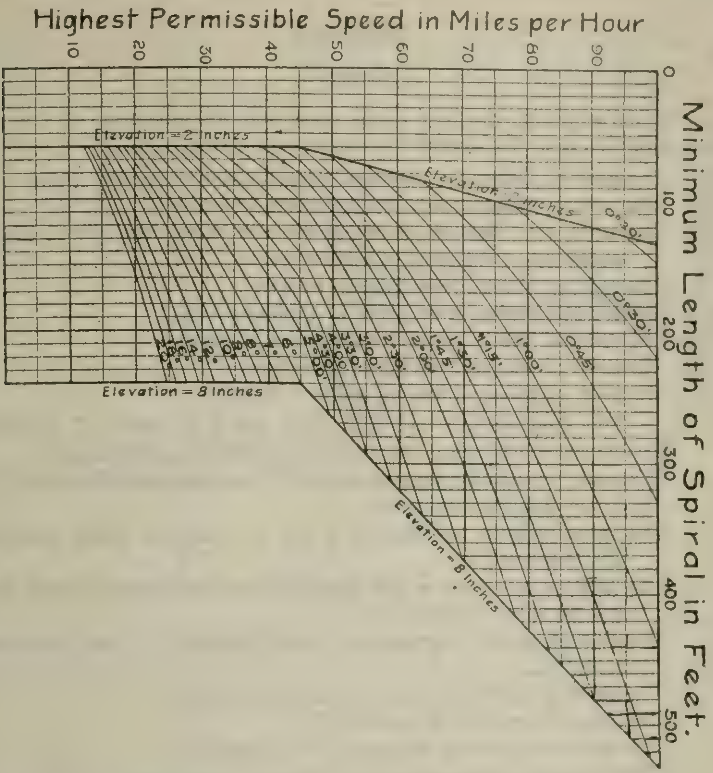
[2] Adopted, Vol. 3, 1902, pp. 55, 56, 67-78; Vol. 5, 1904, pp. 527, 528, 535, 561, 562; Vol. 6, 1905, pp. 753, 754, 759-761; Vol. 10, Part 1, 1909, pp. 400, 429, 430, 461-463, 464; Vol. 12, Part 1, 1911, pp. 402, 447; Vol. 16, 1915, pp. 731, 1145.



MINIMUM LENGTH OF EASEMENT CURVE

Limiting Curves

For all curves which are liable to limit the speed of trains, the length of spiral should equal that indicated on the line marked "Elevation = 8 inches." Longer spirals may be used provided the increased length does not adversely affect the degree of curve or seriously affect the cost of construction.

Minor Curves

For minor curves the length of spiral should never be less than that indicated by the diagram; an increase of about 50 per cent over the indicated length may be desirable where cost is not seriously affected.

Spirals need not be used when elevation required for highest permissible speed is less than two inches.

(3) Which is of the general type of either the Searles spiral, the cubic parabola, or the Holbrook, Crandall, Talbot, and 10-chord spiral.

The 10-chord spiral is recommended. Chords of any part of the spiral length may be used in staking out the 10-chord spiral when the central angle is small. To secure the most accurate results chords approximately one-tenth the length of spiral should be used when the central angle exceeds 15 degrees.

(c) Permanent Monuments

Permanent monuments should be placed at points of tangent, points of spiral, points of change of curvature, summits, and at such other points along curves or tangents as will enable the alinement to be identically reproduced with a transit.

SPIRALS[3]

NOTATION

For curve points, the first initial represents the alinement on the side toward station zero, the second that away from station zero.

T.C.	The point of change in alinement from tangent to circular curve.
C.T.	The point of change from circular curve to tangent.
C.C.	The point of change in degree of circular curve; the point of compound curve, the point of reverse curve.
T.S.	The point of change from tangent to spiral.
S.C.	The point of change from spiral to circular curve.
C.S.	The point of change from circular curve to spiral.
S.T.	The point of change from spiral to tangent.
S.S.	The point of change from one spiral to another.
	The symbols *T.C.* and *C.T.*, *T.S.* and *S.T.*, and *S.C.* and *C.S.* become transposed when the direction of stationing is changed.
a	The angle between the tangent at the *T.S.* and the chord from the *T.S.* to any point on the spiral.
A	The angle between the tangent at the *T.S.* and the chord from the *T.S.* and the *S.C.*
b	The angle at any point on the spiral, between the tangent at that point and the chord from the *T.S.*
B	The angle at the *S.C.* between the chord from the *T.S.* and the tangent at the *S.C.*
c	The chord from the *T.C.* to any point on the spiral.
C	The chord from the *T.S.* to the *S.C.*
d	The degree of curve at any point on the spiral.
D	The degree of central circular curve.
f	The angle between any chord of the spiral (produced if necessary) and the tangent through the *T.S.*
I	The angle between the initial and final tangents; the total central angle of circular curve and spirals.
k	The increase in degree of curve per station on the spiral.
l	The length of the spiral in feet from the *T.S.* to any given point.
L	The length of the spiral in feet from the *T.S.* to the *S.C.*
o	The ordinate of the offset *T.C.*; the distance between the tangent and a parallel tangent to the offset curve.
r	The radius of the osculating circle at any given point of the spiral.
R	The radius of the central circular curve.
s	The length of the spiral in stations from the *T.S.* to any given point.
S	The length of the spiral in stations from the *T.S.* to the *S.C.*
u	The distance on the tangent from the *T.S.* to the intersection with a tangent through any given point of the spiral.
U	The distance on the tangent from the *T.S.* to the intersection with a tangent through the *S.C.*; the longer spiral tangent.
v	The distance on the tangent through any given point from that point to the intersection with the tangent through the *T.S.*

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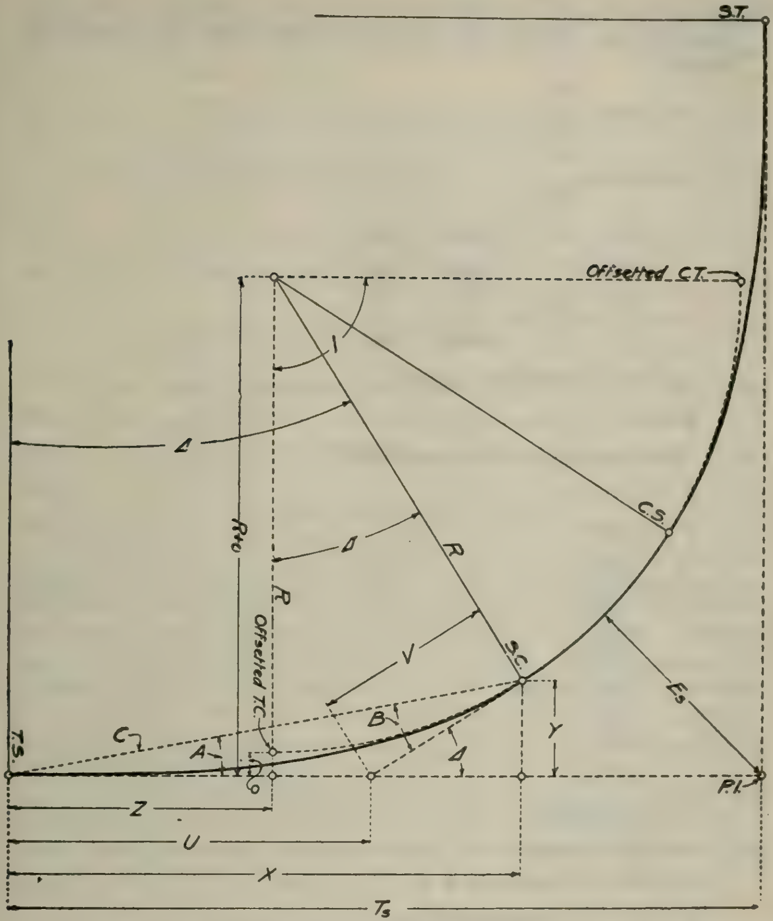
[3] Adopted, Vol. 12, Part 1, 1911, 418, 464; Vol. 16, 1915, pp. 731, 1145.



V	The distance on the tangent through the *S.C.* from the *S.C.* to the intersection with the tangent through the *T.S.*; the shorter spiral tangent.
x	The abscissa or tangent distance of any given point, referred to the *T.S.*
X	The abscissa or tangent distance of the *S.C.*, referred to the *T.S.*
y	The ordinate or tangent offset of any point on the spiral.
Y	The ordinate or tangent offset of the *S.C.*
Z	The abscissa or tangent distance of the offset, *T.C.* referred to the *T.S.*
δ	The central angle of the spiral from the *T.S.* to any given point.
Δ	The central angle of the whole spiral.
Ts	The tangent distance of the spiraled curve; distance from *T.S.* to *P.I.* (point of intersection of tangents).
Es	The external distance of the offset curve.

Formulas for the Exact Determination of the Functions of the Ten-Chord Spiral When the Central Angle Does Not Exceed 45 Degrees

$$\left.\begin{aligned} d &= ks = \frac{kl}{100} \\ D &= kS = \frac{kL}{100} \end{aligned}\right\} \tag{1}$$

$$\left.\begin{aligned} \delta &= \frac{ks^2}{2} = \frac{ds}{2} = \frac{kl^2}{20000} = \frac{dl}{200} \\ \Delta &= \frac{kS^2}{2} = \frac{DS}{2} = \frac{kL^2}{20000} = \frac{DL}{200} \end{aligned}\right\} \tag{2}$$

$$A = \tfrac{1}{3}\Delta - 0.00297\,\Delta^3 \textit{ seconds} \tag{3}$$

$$B = \Delta - A \tag{4}$$

$$C = L\,(\cos 0.3\,\Delta + .004 \operatorname{exsec} \tfrac{3}{4}\,\Delta) \tag{5}$$

$$X = C \cos A \tag{6}$$

$$Y = C \sin A \tag{7}$$

$$U = C\frac{\sin B}{\sin \Delta} \tag{8}$$

$$V = C\frac{\sin A}{\sin \Delta} \tag{9}$$

$$R = \frac{50}{\sin \frac{1}{2} D} \tag{10}$$

$$Z = X - R \sin \Delta \tag{11}$$

$$o = Y - R \operatorname{vers} \Delta \tag{12}$$

$$T_s = (R + o) \tan (\tfrac{1}{2}I) + Z \tag{13}$$

$$E = (R + o) \operatorname{exsec} (\tfrac{1}{2}I) + o \tag{14}$$

Formulas for Field Use

The formulas presented above are best adapted for the preparation of tables. For use in the field, the following empirical formulas are sufficiently accurate and have the advantage that they do not require the computation of the long chord. The formulas can all be applied for the functions of any parts of the spiral without serious error, though they are derived for the completed spiral.

$$\left.\begin{aligned} a &= \tfrac{1}{3}\,\delta \\ A &= \tfrac{1}{3}\,\Delta \end{aligned}\right\} \tag{15}$$

$$\left.\begin{aligned} a &= 10\,ks^2 \textit{ minutes} \\ A &= 10\,kS^2 \textit{ minutes} \end{aligned}\right\} \tag{16}$$

Formulas (15) and (16) are sufficiently accurate for turning deflection when δ (or Δ) does not exceed 15 degrees.

A similar approximation may be used when the transit is set at an intermediate point on the spiral if the included central angle from the transit point to the point of sight, less the included angle from the *T.S.* to the transit point, does not exceed 15 degrees.

$$X = L - L\left(\tfrac{1}{3}\,\mathit{vers}\,\tfrac{3}{4}\Delta + \tfrac{1}{22}\,\mathit{vers}\,\tfrac{1}{2}\Delta\right) \tag{17}$$

$$Y = \frac{L}{39}\left(20\,\sin\tfrac{1}{2}\Delta + 3\,\sin\Delta\right) \tag{18}$$

$$U = L\left(\tfrac{2}{3} + \tfrac{10}{89}\,\mathit{exsec}\,\tfrac{1}{2}\Delta + \tfrac{1}{10}\,\mathit{vers}\,\tfrac{1}{4}\Delta\right) \tag{19}$$

$$V = L\left(\tfrac{1}{3} + \tfrac{10}{89}\,\mathit{exsec}\,\tfrac{1}{2}\Delta\right) \tag{20}$$

$$o = \frac{L}{10}\left(\sin\tfrac{1}{2}\Delta + \sin\tfrac{1}{3}\Delta\right)\cos\tfrac{1}{2}D \tag{21}$$

$$Z = L\left(0.5 - .12885\,\mathit{vers}\,\tfrac{1}{2}\Delta\right) - .073\,D\sin\Delta \tag{22}$$

$$L = \frac{370.82}{\cos\tfrac{21}{60}D}\left(1 + .000018\,Do\right)\sqrt{\frac{o}{D}} \tag{23}$$

STAKING SPIRALS BY OFFSETS

The spiral may be staked by offsets, one-half being offset from the tangent and the other half from circular curve, by making the offsets vary directly as the cube of the distance from the *T.S.* and the *S.C.* This should be done either by using right angle and normal offsets, making the right angle or normal offset for the middle point of the spiral equal one-half *o;* or else by measuring half the total length of the spiral along the tangent, bisecting the distance to the offset *T.C.* for the offset to the middle point of spiral and using oblique offsets between equidistant points on the tangent or circular curve and equidistant points on the spiral.

Both methods will produce spirals somewhat at variance with any theoretical curve, but the variations are of no practical consequence.

If closer adherence to the theoretical curve is desired, the entire spiral may be staked from the tangent by use of the coordinate x and y.

STAKING SPIRALS BY DEFLECTIONS

While any length of chord may be used in staking the spiral, either by offsets or deflections, the most accurate results are obtained by the use of ten equal chords, which is frequently the most convenient method when through-line stationing is not used.

If the spiral be divided into ten equal chords, the first deflection in minutes equals the degree of the main curve times the length of the chord in stations; *e. g.*, when $L = 500$ and $D = 4$, $s_1 = 0.5$ and $a_1 = d$ times $0.5 = 2$ minutes. The remaining deflections are as the squares of the chord numbers, or 4, 9, 16, etc., times the first deflection.

The same limitations apply to these deflections as well as deflections derived from the table of coefficients, as apply to the use of formulas (15) and (16).

When Δ exceeds 15 degrees, formula (3) should be used or else an additional transit point used between the *T.S.* and the *S.T.*

In the latter case the deflection angle from a tangent through a point P' to a point P'' is the deflection for the degree of curve at P' for the distance P' P'' plus or minus the initial spiral deflection angle for the distance P' P''.

This rule applies equally to spirals run in from any point on spiral, from the *S.T.*, or to a spiral connecting two circular curves, the latter being simply the requisite portion of the ordinary spiral. The rule is approximate and should not be used when the central angle from P' to P'' exceeds the central angle from the *T.S.* to P' by more than 15 degrees.

The following table gives the coefficient by which the first chord deflection is to be multiplied to give the deflection to other chord points for various positions of the transit.

COEFFICIENTS OF a_1 FOR DEFLECTION ANGLES TO CHORD POINTS

Deflection Angle to Chord Point Number	Transit at Chord-Point Number										
	0 *T.S.*	1	2	3	4	5	6	7	8	9	10 *S.C.*
0 *T.S.*	0	2	8	18	32	50	72	98	128	162	200
1	1	0	5	14	27	44	65	90	119	152	189
2	4	4	0	8	20	36	56	80	108	140	176
3	9	10	7	0	11	26	45	68	95	126	161
4	16	18	16	10	0	14	32	54	80	110	144
5	25	28	27	22	13	0	17	38	63	92	125
6	36	40	40	36	28	16	0	20	44	72	104
7	49	54	55	52	45	34	19	0	23	50	81
8	64	70	72	70	64	54	40	22	0	26	56
9	81	88	91	90	85	76	63	46	25	0	29
S.C.	100	108	112	112	108	100	88	72	52	28	0

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL

The following table gives values of the deflection angle *A* for values of Δ varying by tenths of degrees, and for the same values of Δ it gives coefficients of *L* for obtaining the long chord *C*, the co-ordinates *X* and *Y* to the end of the spiral and the spiral tangents *U* and *V;* also coefficients of *L* and *D* for obtaining the co-ordinates of *o* and *Z* of the offset point of curve.

To obtain any desired quantity in feet, knowing *D* and choosing a proper value of *L*, or choosing a value of *k* which will give a proper value for *L* and determining *L* from formula (1), derive Δ from equation (2). Opposite Δ find the tabulated value of the coefficient for the desired quantity and multiply it by *L*. For *o* and *Z* apply the coefficients as indicated in the column heading.

Interpolate when necessary.

For the functions of any intermediate point on the spiral as *x*, *y*, etc., proceed exactly in the same manner as for the completed spiral.

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.

Δ	A	C/L	X/L	Y/L
0.0°	0° 00′ 00″	1.000 000	1.000 000	.000 000
0.1°	0° 02′ 00″	1.000 000	1.000 000	.000 582
0.2°	0° 04′ 00″	.999 999	.999 999	.001 164
0.3°	0° 06′ 00″	.999 999	.999 997	.001 745
0.4°	0° 08′ 00″	.999 998	.999 995	.002 327
0.5°	0° 10′ 00″	.999 997	.999 992	.002 909
0.6°	0° 12′ 00″	.999 995	.999 989	.003 491
0.7°	0° 14′ 00″	.999 993	.999 985	.004 072
0.8°	0° 16′ 00″	.999 991	.999 981	.004 654
0.9°	0° 18′ 00″	.999 989	.999 975	.005 236
1.0°	0° 20′ 00″	.999 987	.999 970	.005 818
1.1°	0° 22′ 00″	.999 984	.999 963	.006 399
1.2°	0° 24′ 00″	.999 981	.999 956	.006 981
1.3°	0° 26′ 00″	.999 977	.999 949	.007 563
1.4°	0° 28′ 00″	.999 974	.999 941	.008 145
1.5°	0° 30′ 00″	.999 970	.999 932	.008 726
1.6°	0° 32′ 00″	.999 966	.999 922	.009 308
1.7°	4° 34′ 00″	.999 961	.999 912	.009 890
1.8°	0° 36′ 00″	.999 957	.999 902	.010 471
1.9°	0° 38′ 00″	.999 952	.999 891	.011 053
2.0°	0° 40′ 00″	.999 947	.999 879	.011 635
2.1°	0° 42′ 00″	.999 941	.999 866	.012 216
2.2°	0° 44′ 00″	.999 935	.999 853	.012 798
2.3°	0° 46′ 00″	.999 929	.999 840	.013 379
2.4°	0° 48′ 00″	.999 923	.999 826	.013 961
2.5°	0° 50′ 00″	.999 916	.999 811	.014 542
2.6°	0° 52′ 00″	.999 910	.999 795	.015 124
2.7°	0° 54′ 00″	.999 903	.999 779	.015 706
2.8°	0° 56′ 00″	.999 895	.999 763	.016 287
2.9°	0° 58′ 00″	.999 888	.999 745	.016 868
3.0°	1° 00′ 00″	.999 880	.999 727	.017 450
3.1°	1° 02′ 00″	.999 872	.999 709	.018 031
3.2°	1° 04′ 00″	.999 863	.999 690	.018 613
3.3°	1° 06′ 00″	.999 854	.999 670	.019 194
3.4°	1° 08′ 00″	.999 846	.999 650	.019 775
3.5°	1° 10′ 00″	.999 836	.999 629	.020 357
3.6°	1° 12′ 00″	.999 827	.999 608	.020 938
3.7°	1° 14′ 00″	.999 817	.999 585	.021 519
3.8°	1° 16′ 00″	.999 807	.999 563	.022 101
3.9°	1° 18′ 00″	.999 797	.999 539	.022 682
4.0°	1° 20′ 00″	.999 786	.999 515	.023 263
4.1°	1° 22′ 00″	.999 775	.999 491	.023 844
4.2°	1° 24 00″	.999 764	.999 466	.024 425
4.3°	1° 26′ 00″	.999 753	.999 440	.025 006
4.4°	1° 28′ 00″	.999 741	.999 414	.025 588
4.5°	1° 30′ 00″	.999 729	.999 387	.026 169
4.6°	1° 32′ 00″	.999 717	.999 359	.026 750
4.7°	1° 34′ 00″	.999 705	.999 331	.027 331
4.8°	1° 36′ 00″	.999 692	.999 302	.027 911
4.9°	1° 38′ 00″	.999 679	.999 273	.028 492
5.0°	1° 40′ 00″	.999 666	.999 243	029 073

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.666 667	.333 333	.000 000	.000 00	.500 000	.000 00	0.0°
.666 667	.333 333	.000 145	.000 00	.500 000	.000 13	0.1°
.666 667	.333 334	.000 291	.000 00	.500 000	.000 25	0.2°
.666 668	.333 334	.000 436	.000 00	.500 000	.000 38	0.3°
.666 668	.333 335	.000 582	.000 00	.499 999	.000 51	0.4°
.666 669	.333 336	.000 727	.000 00	.499 999	.000 64	0.5°
.666 671	.333 337	.000 873	.000 00	.499 998	.000 76	0.6°
.666 672	.333 338	.001 018	.000 01	.499 998	.000 89	0.7°
.666 674	.333 340	.001 164	.000 01	.499 997	.001 02	0.8°
.666 675	.333 341	.001 309	.000 01	.499 996	.001 15	0.9°
.666 677	.333 343	.001 454	.000 01	.499 995	.001 27	1.0°
.666 680	.333 345	.001 600	.000 01	.499 994	.001 40	1.1°
.666 682	.333 347	.001 745	.000 02	.499 993	.001 53	1.2°
.666 685	.333 350	.001 891	.000 02	.499 992	.001 66	1.3°
.666 688	.333 352	.002 036	.000 02	.499 990	.001 78	1.4°
.666 691	.333 355	.002 182	.000 03	.499 989	.001 91	1.5°
.666 694	.333 358	.002 327	.000 03	.499 987	.002 04	1.6°
.666 698	.333 362	.002 472	.000 03	.499 986	.002 17	1.7°
.666 701	.333 365	.002 618	.000 04	.499 984	.002 29	1.8°
.666 705	.333 369	.002 763	.000 04	.499 982	.002 42	1.9°
.666 710	.333 372	.002 909	.000 04	.499 980	.002 55	2.0°
.666 714	.333 376	.003 054	.000 05	.499 978	.002 68	2.1°
.666 719	.333 381	.003 200	.000 05	.499 976	.002 80	2.2°
.666 723	.333 385	.003 345	.000 06	.499 974	.002 93	2.3°
.666 728	.333 390	.003 490	.000 06	.499 972	.003 06	2.4°
.666 734	.333 394	.003 636	.000 07	.499 969	.003 18	2.5°
.666 739	.333 399	.003 781	.000 08	.499 967	.003 31	2.6°
.666 745	.333 405	.003 927	.000 08	.499 964	.003 44	2.7°
.666 751	.333 410	.004 072	.000 09	.499 962	.003 57	2.8°
.666 757	.333 415	.004 218	.000 09	.499 959	.003 69	2.9°
.666 763	.333 421	.004 363	.000 10	.499 956	.003 82	3.0°
.666 770	.333 427	.004 508	.000 11	.499 953	.003 95	3.1°
.666 776	.333 433	.004 654	.000 11	.499 950	.004 07	3.2°
.666 783	.333 440	.004 799	.000 12	.499 947	.004 20	3.3°
.666 791	.333 446	.004 945	.000 13	.499 943	.004 33	3.4°
.666 798	.333 453	.005 090	.000 14	.499 940	.004 46	3.5°
.666 806	.333 460	.005 235	.000 14	.499 936	.004 58	3.6°
.666 813	.333 467	.005 381	.000 15	.499 933	.004 71	3.7°
.666 822	.333 474	.005 526	.000 16	.499 929	.004 84	3.8°
.666 830	.333 482	.005 671	.000 17	.499 925	.004 97	3.9°
.666 838	.333 490	.005 817	.000 18	499 922	.005 09	4.0°
.666 847	.333 498	.005 962	.000 19	.499 918	.005 22	4.1°
.666 856	.333 506	.006 108	.000 20	.499 914	.005 35	4.2°
.666 865	.333 514	.006 253	.000 21	.499 909	.005 47	4.3°
.666 874	.333 522	.006 398	.000 22	.499 905	.005 60	4.4°
.666 884	.333 531	.006 544	.000 23	.499 901	.005 73	4.5°
.666 894	.333 540	.006 689	.000 24	.499 896	.005 85	4.6°
.666 904	.333 549	.006 834	.000 25	.499 892	.005 98	4.7°
.666 914	.333 558	.006 980	.000 26	.499 887	.006 11	4.8°
.666 924	.333 568	.007 125	.000 27	.499 882	.006 24	4.9°
.666 935	.333 578	.007 270	.000 28	.499 877	.006 36	5.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL—Cont'd.

Δ	A	$\frac{C}{L}$	$\frac{X}{L}$	$\frac{Y}{L}$
5.0°	1° 40′ 00″	.999 666	.999 243	.029 073
5.1°	1° 42′ 00″	.999 652	.999 212	.029 654
5.2°	1° 44′ 00″	.999 639	.999 181	.030 235
5.3°	1° 46′ 00″	.999 625	.999 150	.030 816
5.4°	1° 48′ 00″	.999 610	.999 117	.031 396
5.5°	1° 50′ 00″	.999 596	.999 084	.031 977
5.6°	1° 51′ 59″	.999 581	.999 051	.032 558
5.7°	1° 53′ 59″	.999 566	.999 016	.033 138
5.8°	1° 55′ 59″	.999 550	.998 982	.033 719
5.9°	1° 57′ 59″	.999 535	.998 946	.034 299
6.0°	1° 59′ 59″	.999 519	.998 910	.034 880
6.1°	2° 01′ 59″	.999 503	.998 874	.035 460
6.2°	2° 03′ 59″	.999 486	.998 836	.036 040
6.3°	2° 05′ 59″	.999 470	.998 799	.036 621
6.4°	2° 07′ 59″	.999 453	.998 760	.037 201
6.5°	2° 09′ 59″	.999 435	.998 721	.037 781
6.6°	2° 11′ 59″	.999 418	.998 681	.038 361
6.7°	2° 13′ 59″	.999 400	.998 641	.038 941
6.8°	2° 15′ 59″	.999 382	.998 600	.039 522
6.9°	2° 17′ 59″	.999 364	.998 559	.040 102
7.0°	2° 19′ 59″	.999 345	.998 517	.040 682
7.1°	2° 21′ 59″	.999 326	.998 474	.041 261
7.2°	2° 23′ 59″	.999 307	.998 431	.041 841
7.3°	2° 25′ 59″	.999 288	.998 387	.042 421
7.4°	2° 27′ 59″	.999 268	.998 343	.043 001
7.5°	2° 29′ 59″	.999 248	.998 298	.043 581
7.6°	2° 31′ 59″	.999 228	.998 252	.044 160
7.7°	2° 33′ 59″	.999 208	.998 206	.044 740
7.8°	2° 35′ 59″	.999 187	.998 159	.045 319
7.9°	2° 37′ 59″	.999 166	.998 111	.045 899
8.0°	2° 39′ 58″	.999 145	.998 063	.046 478
8.1°	2° 41′ 58″	.999 123	.998 015	.047 058
8.2°	2° 43′ 58″	.999 102	.997 965	.047 637
8.3°	2° 45′ 58″	.999 080	.997 915	.048 216
8.4°	2° 47′ 58″	.999 057	.997 865	.048 795
8.5°	2° 49′ 58″	.999 035	.997 814	.049 374
8.6°	2° 51′ 58″	.999 012	.997 762	.049 953
8.7°	2° 53′ 58″	.998 989	.997 710	.050 532
8.8°	2° 55′ 58″	.998 965	.997 657	.051 111
8.9°	2° 57′ 58″	.998 942	.997 603	.051 690
9.0°	2° 59′ 58″	.998 918	.997 549	.052 269
9.1°	3° 01′ 58″	.998 894	.997 495	.052 848
9.2°	3° 03′ 58″	.998 869	.997 439	.053 426
9.3°	3° 05′ 58	.998 844	.997 383	.054 005
9.4°	3° 07′ 58″	.998 819	.997 327	.054 583
9.5°	3° 09′ 57″	.998 794	.997 270	.055 162
9.6°	3° 11′ 57″	.998 769	.997 212	.055 740
9.7°	3° 13′ 57″	.998 743	.997 154	.056 318
9.8°	3° 15′ 57″	.998 717	.997 095	.056 897
9.9°	3° 17′ 57″	.998 691	.997 035	.057 475
10.0°	3° 19′ 57″	.998 664	.996 975	.058 053

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.666 935	.333 578	.007 270	.000 28	.499 877	.006 36	5.0°
.666 946	.333 587	.007 416	.000 29	.499 872	.006 49	5.1°
.666 957	.333 598	.007 561	.000 30	.499 867	.006 62	5.2°
.666 968	.333 608	.007 706	.000 31	.499 862	.006 74	5.3°
.666 979	.333 618	.007 852	.000 32	.499 857	.006 87	5.4°
.666 991	.333 629	.007 997	.000 34	.499 852	.007 00	5.5°
.667 003	.333 640	.008 142	.000 35	.499 846	.007 12	5.6°
.667 015	.333 651	.008 288	.000 36	.499 841	.007 25	5.7°
.667 028	.333 662	.008 433	.000 37	.499 835	.007 38	5.8°
.667 040	.333 674	.008 578	.000 39	.499 829	.007 50	5.9°
.667 053	.333 685	.008 724	.000 40	.499 824	.007 63	6.0°
.667 066	.333 697	.008 869	.000 41	.499 818	.007 76	6.1°
.667 079	.333 709	.009 014	.000 43	.499 812	.007 88	6.2°
.667 093	.333 721	.009 159	.000 44	.499 805	.008 01	6.3°
.667 106	.333 734	.009 305	.000 45	.499 799	.008 14	6.4°
.667 120	.333 746	.009 450	.000 47	.499 793	.008 26	6.5°
.667 134	.333 759	.009 595	.000 48	.499 786	.008 39	6.6°
.667 148	.333 772	.009 740	.000 50	.499 780	.008 52	6.7°
.667 163	.333 785	.009 886	.000 51	.499 773	.008 64	6.8°
.667 178	.333 799	.010 031	.000 53	.499 767	.008 77	6.9°
.667 193	.333 812	.010 176	.000 54	.499 760	.008 90	7.0°
.667 208	.333 826	.010 321	.000 56	.499 753	.009 02	7.1°
.667 223	.333 840	.010 467	.000 58	.499 746	.009 15	7.2°
.667 239	.333 854	.010 612	.000 59	.499 739	.009 28	7.3°
.667 255	.333 869	.010 757	.000 61	.499 732	.009 40	7.4°
.667 271	.333 883	.010 902	.000 62	.499 724	.009 53	7.5°
.667 287	.333 898	.011 048	.000 64	.499 717	.009 65	7.6°
.667 303	.333 913	.011 193	.000 66	.499 709	.009 78	7.7°
.667 320	.333 928	.011 338	.000 68	.499 702	.009 91	7.8°
.667 337	.333 944	.011 483	.000 69	.499 694	.010 03	7.9°
.667 354	.333 959	.011 628	.000 71	.499 686	.010 16	8.0°
.667 371	.333 975	.011 773	.000 73	.499 678	.010 29	8.1°
.667 389	.333 991	.011 919	.000 75	.499 670	.010 41	8.2°
.667 407	.334 007	.012 064	.000 76	.499 662	.010 54	8.3°
.667 424	.334 024	.012 209	.000 78	.499 654	.010 66	8.4°
.667 443	.334 040	.012 354	.000 80	.499 646	.010 79	8.5°
.667 461	.334 057	.012 499	.000 82	.499 637	.010 92	8.6°
.667 480	.334 074	.012 644	.000 84	.499 629	.011 04	8.7°
.667 499	.334 091	.012 789	.000 86	.499 620	.011 17	8.8°
.667 518	.334 109	.012 935	.000 88	.499 612	.011 29	8.9°
.667 537	.334 126	.013 080	.000 90	.499 603	.011 42	9.0°
.667 556	.334 144	.013 225	.000 92	.499 594	.011 55	9.1°
.667 576	.334 162	.013 370	.000 94	.499 585	.011 67	9.2°
.667 596	.334 180	.013 515	.000 96	.499 576	.011 80	9.3°
.667 616	.334 198	.013 660	.000 98	.499 567	.011 92	9.4°
.667 636	.334 217	.013 805	.001 00	.499 558	.012 05	9.5°
.667 657	.334 236	.013 950	.001 02	.499 548	.012 17	9.6°
.667 678	.334 255	.014 095	.001 04	.499 539	.012 30	9.7°
.667 699	.334 274	.014 240	.001 07	.499 529	.012 43	9.8°
.667 720	.334 293	.014 385	.001 09	.499 520	.012 55	9.9°
.667 742	.334 313	.014 530	.001 11	.499 510	.012 68	10.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

Δ	A	$\frac{C}{L}$	$\frac{X}{L}$	$\frac{Y}{L}$
10.0°	3° 19′ 57″	.998 664	.996 975	.058 053
10.1°	3° 21′ 57″	.998 637	.996 915	.058 631
10.2°	3° 23′ 57″	.998 610	.996 853	.059 209
10.3°	3° 25′ 57″	.998 583	.996 791	.059 787
10.4°	3° 27′ 57″	.998 555	.996 729	.060 364
10.5°	3° 29′ 57″	.998 527	.996 666	.060 942
10.6°	3° 31′ 56″	.998 499	.996 602	.061 520
10.7°	3° 33′ 56″	.998 471	.996 538	.062 097
10.8°	3° 35′ 56″	.998 442	.996 473	.062 675
10.9°	3° 37′ 56″	.998 413	.996 407	.063 252
11.0°	3° 39′ 56″	.998 384	.996 341	.063 829
11.1°	3° 41′ 56″	.998 354	.996 274	.064 406
11.2°	3° 43′ 56″	.998 324	.996 207	.064 984
11.3°	3° 45′ 56″	.998 294	.996 139	.065 561
11.4°	3° 47′ 56″	.998 264	.996 071	.066 138
11.5°	3° 49′ 55″	.998 233	.996 002	.066 714
11.6°	3° 51 55″	.998 203	.995 932	.067 291
11.7°	3° 53′ 55″	.998 171	.995 862	.067 868
11.8°	3° 55′ 55″	.998 140	.995 791	.068 445
11.9°	3° 57′ 55″	.998 108	.995 719	.069 021
12.0°	3° 59′ 55″	.998 077	.995 647	.069 598
12.1°	4° 01′ 55″	998 044	.995 574	.070 174
12.2°	4° 03′ 55″	.998 012	.995 501	.070 750
12.3°	4° 05′ 54″	.997 979	.995 427	.071 326
12.4°	4° 07′ 54″	.997 946	.995 353	.071 902
12.5°	4° 09′ 54″	.997 913	.995 278	.072 478
12.6°	4° 11′ 54″	.997 880	.995 202	.073 054
12.7°	4° 13′ 54″	.997 846	.995 126	.073 630
12.8°	4° 15′ 54″	.997 812	.995 049	.074 206
12.9°	4° 17′ 54″	.997 777	.994 971	.074 781
13.0°	4° 19′ 53″	.997 743	.994 893	.075 357
13.1°	4° 21′ 53″	.997 708	.994 814	.075 932
13.2°	4° 23′ 53″	.997 673	.994 735	.076 508
13.3°	4° 25′ 53″	.997 638	.994 655	.077 083
13.4°	4° 27′ 53″	.997 602	.994 575	.077 658
13.5°	4° 29′ 53″	.997 566	.994 494	.078 233
13.6°	4° 31′ 53″	.997 530	.994 412	.078 808
13.7°	4° 33′ 52″	.997 493	.994 330	.079 383
13.8°	4° 35′ 52″	.997 457	.994 247	.079 957
13.9°	4° 37′ 52	.997 420	.994 163	.080 532
14.0°	4° 39′ 52″	.997 383	.994 079	.081 106
14.1°	4° 41′ 52″	.997 345	.993 995	.081 681
14.2°	4° 43′ 51″	.997 307	.993 909	.082 255
14.3°	4° 45′ 51″	.997 269	.993 824	.082 829
14.4°	4° 47′ 51″	.997 231	.993 737	.083 403
14.5°	4° 49′ 51″	.997 192	.993 650	.083 977
14.6°	4° 51′ 51″	.997 154	.993 563	.084 551
14.7°	4° 53′ 51″	.997 115	.993 474	.085 125
14.8°	4° 55′ 50″	.997 075	.993 385	.085 699
14.9°	4° 57′ 50″	.997 036	.993 296	.086 272
15.0°	4° 59′ 50″	996 996	.993 206	.086 846

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.667 742	.334 313	.014 530	.001 11	.499 510	.012 68	10.0°
.667 763	.334 332	.014 675	.001 13	.499 500	.012 80	10.1°
.667 785	.334 352	.014 820	.001 15	.499 490	.012 93	10.2°
.667 807	.334 373	.014 965	.001 18	.499 480	.013 05	10.3°
.667 830	.334 393	.015 110	.001 20	.499 470	.013 18	10.4°
.667 852	.334 413	.015 255	.001 22	.499 460	.013 30	10.5°
.667 875	.334 434	.015 400	.001 25	.499 449	.013 43	10.6°
.667 898	.334 455	.015 545	.001 27	.499 439	.013 55	10.7°
.667 921	.334 476	.015 690	.001 29	.499 428	.013 68	10.8°
.667 944	.334 498	.015 835	.001 32	.499 418	.013 80	10.9°
.667 968	.334 519	.015 980	.001 34	.499 407	.013 93	11.0°
.667 992	.334 541	.016 125	.001 37	.499 396	.014 05	11.1°
.668 016	.334 563	.016 270	.001 39	.499 385	.014 18	11.2°
.668 040	.334 585	.016 415	.001 42	.499 374	.014 30	11.3°
.668 065	.334 607	.016 560	.001 44	.499 363	.014 43	11.4°
.668 089	.334 630	.016 704	.001 47	.499 352	.014 55	11.5°
.668 114	.334 653	.016 849	.001 49	.499 341	.014 68	11.6°
.668 140	.334 676	.016 994	.001 52	.499 329	.014 80	11.7°
.668 165	.334 699	.017 139	.001 54	.499 318	.014 93	11.8°
.668 191	.334 722	.017 284	.001 57	.499 306	.015 05	11.9°
.668 216	.334 746	.017 429	.001 60	.499 294	.015 18	12.0°
.668 242	.334 769	.017 574	.001 62	.499 283	.015 30	12.1°
.668 269	.334 793	.017 718	.001 65	.499 271	.015 43	12.2°
.668 295	.334 817	.017 863	.001 68	.499 259	.015 55	12.3°
.668 322	.334 842	.018 008	.001 70	.499 247	.015 68	12.4°
.668 349	.334 866	.018 153	.001 73	.499 234	.015 80	12.5°
.668 376	.334 891	.018 298	.001 76	.499 222	.015 92	12.6°
.668 403	.334 916	.018 442	.001 79	.499 210	.016 05	12.7°
.668 431	.334 941	.018 587	.001 81	.499 197	.016 17	12.8°
.668 459	.334 967	.018 732	.001 84	.499 185	.016 30	12.9°
.668 487	.334 992	.018 877	.001 87	.499 172	.016 42	13.0°
.668 515	.335 018	.019 021	.001 90	.499 159	.016 55	13.1°
.668 543	.335 044	.019 166	.001 93	.499 146	.016 67	13.2°
.668 572	.335 070	.019 311	.001 96	.499 133	.016 79	13.3°
.668 601	.335 096	.019 455	.001 99	.499 120	.016 92	13.4°
.668 630	.335 123	.019 600	.002 02	.499 107	.017 04	13.5°
.668 660	.335 150	.019 745	.002 05	.499 094	.017 17	13.6°
.668 689	.335 177	.019 889	.002 08	.499 081	.017 29	13.7°
.668 719	.335 204	.020 034	.002 11	.499 067	.017 41	13.8°
.668 749	.335 231	.020 179	.002 14	.499 054	.017 54	13.9°
.668 779	.335 259	.020 323	.002 17	.499 040	.017 66	14.0°
.668 810	.335 287	.020 468	.002 20	.499 026	.017 78	14.1°
.668 840	.335 315	.020 612	.002 23	.499 012	.017 91	14.2°
.668 871	.335 343	.020 757	.002 26	.498 998	.018 03	14.3°
.668 902	.335 371	.020 902	.002 29	.498 984	.018 15	14.4°
.668 934	.335 400	.021 046	.002 33	.498 970	.018 28	14.5°
.668 965	.335 429	.021 191	.002 36	.498 956	.018 40	14.6°
.668 997	.335 458	.021 335	.002 39	.498 942	.018 52	14.7°
.669 029	.335 487	.021 480	.002 42	.498 927	.018 65	14.8°
.669 061	.335 516	.021 624	.002 45	.498 913	.018 77	14.9°
.669 094	.335 546	.021 769	.002 49	.498 898	.018 89	15.0°

Δ	A	$\frac{C}{L}$	$\frac{X}{L}$	$\frac{Y}{L}$
15.0°	4° 59′ 50″	.996 996	.993 206	.086 846
15.1°	5° 01′ 50″	.996 956	.993 115	.087 419
15.2°	5° 03′ 50″	.996 915	.993 024	.087 992
15.3°	5° 05′ 49″	.996 874	.992 932	.088 565
15.4°	5° 07′ 49″	.996 833	.992 840	.089 138
15.5°	5° 09′ 49″	.996 792	.992 747	.089 711
15.6°	5° 11′ 49″	.996 751	.992 654	.090 284
15.7°	5° 13′ 49″	.996 709	.992 559	.090 856
15.8°	5° 15′ 48″	.996 667	.992 465	.091 429
15.9°	5° 17′ 48″	.996 625	.992 369	.092 001
16.0°	5° 19′ 48″	.996 582	.992 273	.092 574
16.1°	5° 21′ 48″	.996 539	.992 177	.093 146
16.2°	5° 23′ 47″	.996 496	.992 080	.093 718
16.3°	5° 25′ 47″	.996 453	.991 982	.094 290
16.4°	5° 27′ 47″	.996 409	.991 884	.094 862
16.5°	5° 29′ 47″	.996 366	.991 785	.095 433
16.6°	5° 31′ 46″	.996 321	.991 685	.096 005
16.7°	5° 33′ 46″	.996 277	.991 585	.096 576
16.8°	5° 35′ 46″	.996 232	.991 484	.097 148
16.9°	5° 37′ 46″	.996 187	.991 383	.097 719
17.0°	5° 39′ 45″	.996 142	.991 281	.098 290
17.1°	5° 41′ 45″	.996 097	.991 179	.098 861
17.2°	5° 43′ 45″	.996 051	.991 076	.099 432
17.3°	5° 45′ 45″	.996 005	.990 972	.100 002
17.4°	5° 47′ 44″	.995 959	.990 868	.100 573
17.5°	5° 49′ 44″	.995 912	.990 763	.101 143
17.6°	5° 51′ 44″	.995 865	.990 658	.101 713
17.7°	5° 53′ 44″	.995 818	.990 552	.102 284
17.8°	5° 55′ 43″	.995 771	.990 445	.102 854
17.9°	5° 57′ 43″	.995 723	.990 338	.103 424
18.0°	5° 59′ 43″	.995 676	.990 230	.103 993
18.1°	6° 01′ 42″	.995 628	.990 122	.104 563
18.2°	6° 03′ 42″	.995 579	.990 013	.105 132
18.3°	6° 05′ 42″	.995 530	.989 903	.105 702
18.4°	6° 07′ 42″	.995 482	.989 793	.106 271
18.5°	6° 09 41″	.995 432	.989 682	.106 840
18.6°	6° 11′ 41″	.995 383	.989 571	107 409
18.7°	6° 13′ 41″	.995 333	.989 459	.107 978
18.8°	6° 15′ 40″	.995 283	.989 347	.108 547
18.9°	6° 17′ 40″	.995 233	.989 233	.109 115
19.0°	6° 19′ 40″	.995 183	.989 120	.109 683
19.1°	6° 21′ 39″	.995 132	.989 005	.110 252
19.2°	6° 23′ 39″	.995 081	.988 891	.110 820
19.3°	6° 25′ 39″	.995 029	.988 775	.111 388
19.4°	6° 27′ 38″	.994 978	.988 659	.111 956
19.5°	6° 29′ 38″	.994 926	.988 543	.112 523
19.6°	6° 31′ 38″	.994 874	.988 425	.113 091
19.7°	6° 33′ 37″	.994 822	.988 308	.113 658
19.8°	6° 35′ 37″	.994 769	.988 189	.114 225
19.9°	6° 37′ 37″	.994 716	.988 070	.114 793
20.0°	6° 39′ 36″	.994 663	.987 951	.115 360

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.669 094	.335 546	.021 769	.002 49	.498 898	.018 89	15.0°
.669 126	.335 576	.021 913	.002 52	.498 883	.019 02	15.1°
.669 159	.335 606	.022 058	.002 55	.498 869	.019 14	15.2°
.669 192	.335 636	.022 202	.002 59	.498 854	.019 26	15.3°
.669 226	.335 666	.022 347	.002 62	.498 839	.019 39	15.4°
.669 259	.335 697	.022 491	.002 65	.498 824	.019 51	15.5°
.669 293	.335 728	.022 635	.002 69	.498 808	.019 63	15.6°
.669 327	.335 759	.022 780	.002 72	.498 793	.019 75	15.7°
.669 361	.335 790	.022 924	.002 76	.498 778	.019 88	15.8°
.669 396	.335 821	.023 069	.002 79	.498 762	.020 00	15.9°
.669 431	.335 853	.023 213	.002 83	.498 747	.020 12	16.0°
.669 465	.335 885	.023 357	.002 86	.498 731	.020 24	16.1°
.669 501	.335 917	.023 502	.002 90	.498 715	.020 37	16.2°
.669 536	.335 949	.023 646	.002 93	.498 699	.020 49	16.3°
.669 572	.335 982	.023 790	.002 97	.498 683	.020 61	16.4°
.669 607	.336 014	.023 935	.003 01	.498 667	.020 73	16.5°
.669 643	.336 047	.024 079	.003 04	.498 651	.020 86	16.6°
.669 680	.336 080	.024 223	.003 08	.498 635	.020 98	16.7°
.669 716	.336 114	.024 367	.003 12	.498 618	.021 10	16.8°
.669 753	.336 147	.024 512	.003 15	.498 602	.021 22	16.9°
.669 790	.336 181	.024 656	.003 19	.498 585	.021 34	17.0°
.669 827	.336 215	.024 800	.003 23	.498 569	.021 46	17.1°
.669 864	.336 249	.024 944	.003 26	.498 552	.021 59	17.2°
.669 902	.336 283	.025 088	.003 30	.498 535	.021 71	17.3°
.669 940	.336 318	.025 233	.003 34	.498 518	.021 83	17.4°
.669 978	.336 353	.025 377	.003 38	.498 501	.021 95	17.5°
.670 016	.336 388	.025 521	.003 42	.498 484	.022 07	17.6°
.670 055	.336 423	.025 665	.003 46	.498 466	.022 19	17.7°
.670 093	.336 458	.025 809	.003 49	.498 449	.022 32	17.8°
.670 132	.336 494	.025 953	.003 53	.498 432	.022 44	17.9°
.670 172	.336 529	.026 097	.003 57	.498 414	.022 56	18.0°
.670 211	.336 565	.026 241	.003 61	.498 397	.022 68	18.1°
.670 251	.336 602	.026 385	.003 65	.498 379	.022 80	18.2°
.670 290	.336 638	.026 529	.003 69	.498 361	.022 92	18.3°
.670 331	.336 675	.026 673	.003 73	.498 343	.023 04	18.4°
.670 371	.336 711	.026 817	.003 77	.498 325	.023 16	18.5°
.670 411	.336 748	.026 961	.003 81	.498 307	.023 28	18.6°
.670 452	.336 786	.027 105	.003 85	.498 289	.023 40	18.7°
.670 493	.336 823	.027 249	.003 89	.498 270	.023 53	18.8°
.670 534	.336 861	.027 393	.003 94	.498 252	.023 65	18.9°
.670 576	.336 899	.027 537	.003 98	.498 233	.023 77	19.0°
.670 618	.336 937	.027 681	.004 02	.498 215	.023 89	19.1°
.670 660	.336 975	.027 825	.004 06	.498 196	.024 01	19.2°
.670 702	.337 013	.027 969	.004 10	.498 177	.024 13	19.3°
.670 744	.337 052	.028 113	.004 14	.498 158	.024 25	19.4°
.670 787	.337 091	.028 257	.004 19	.498 139	.024 37	19.5°
.670 829	.337 130	.028 400	.004 23	.498 120	.024 49	19.6°
.670 873	.337 169	.028 544	.004 27	.498 101	.024 61	19.7°
.670 916	.337 209	.028 688	.004 32	.498 082	.024 73	19.8°
.670 959	.337 249	.028 832	.004 36	.498 062	.024 85	19.9°
.671 003	.337 289	.028 976	.004 40	.498 043	.024 97	20.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL—Cont'd.

Δ	A	$\frac{C}{L}$	$\frac{X}{L}$	$\frac{Y}{L}$
20.0°	6° 39′ 36″	.994 663	.987 951	.115 360
20.1°	6° 41′ 36″	.994 610	.987 831	.115 926
20.2°	6° 43 36°	.994 556	.987 710	.116 493
20.3°	6° 45′ 35″	.994 502	.987 589	.117 060
20.4°	6° 47′ 35″	.994 448	.987 467	.117 626
20.5°	6° 49′ 34″	.994 393	.987 344	.118 192
20.6°	6° 51′ 34″	.994 339	.987 221	.118 758
20.7°	6° 53′ 34″	.994 284	.987 098	.119 324
20.8°	6° 55′ 33″	.994 228	.986 973	.119 890
20.9°	6° 57′ 33″	.994 173	.986 849	.120 455
21.0°	6° 59′ 32″	.994 117	.986 723	.121 021
21.1°	7° 01′ 32″	.994 061	.986 597	.121 586
21.2°	7° 03′ 32″	.994 005	.986 471	.122 151
21.3°	7° 05′ 31″	.993 948	.986 343	.122 716
21.4°	7° 07′ 31″	.993 891	.986 216	.123 281
21.5°	7° 09′ 30″	.993 834	.986 087	.123 846
21.6°	7° 11′ 30″	.993 777	.985 959	.124 410
21.7°	7° 13′ 30″	.993 719	.985 829	.124 975
21.8°	7° 15′ 29″	.993 661	.985 699	.125 539
21.9°	7° 17′ 29″	.993 603	.985 568	.126 103
22.0°	7° 19′ 28″	.993 545	.985 437	.126 667
22.1°	7° 21′ 28″	.993 486	.985 305	.127 230
22.2°	7° 23′ 28″	.993 427	.985 173	.127 794
22.3°	7° 25′ 27″	.993 368	.985 040	.128 357
22.4°	7° 27′ 27″	.993 308	.984 906	.128 920
22.5°	7° 29′ 26″	.993 248	.984 772	.129 483
22.6°	7° 31′ 26″	993 188	.984 638	.130 046
22.7°	7° 33′ 25″	.993 128	.984 502	.130 609
22.8°	7° 35′ 25″	.993 068	.984 366	.131 172
22.9°	7° 37′ 24″	.993 007	.984 230	.131 734
23.0°	7° 39′ 24″	.992 946	.984 093	.132 296
23.1°	7° 41′ 23″	.992 884	.983 955	.132 858
23.2°	7° 43′ 23″	.992 823	.983 817	.133 420
23.3°	7° 45′ 22″	.992 761	.983 678	.133 982
23.4°	7° 47′ 22″	.992 699	.983 539	.134 543
23.5°	7° 49′ 21″	.992 636	.983 399	.135 105
23.6°	7° 51′ 21″	.992 574	.983 259	.135 666
23.7°	7° 53′ 20″	.992 511	.983 118	.136 227
23.8°	7° 55′ 20″	.992 448	.982 976	.136 788
23.9°	7° 57′ 19″	.992 384	.982 834	.137 348
24.0°	7° 59′ 19″	.992 321	.982 691	.137 909
24.1°	8° 01′ 18″	.992 257	.982 547	.138 469
24.2°	8° 03′ 18″	.992 192	.982 403	.139 029
24.3°	8° 05′ 17″	.992 128	.982 259	.139 589
24.4°	8° 07′ 17″	.992 063	.982 114	.140 149
24.5°	8° 09′ 16″	.991 998	.981 968	.140 708
24.6°	8° 11′ 16″	.991 933	.981 822	.141 268
24.7°	8° 13′ 15″	.991 867	.981 675	.141 827
24.8°	8° 15′ 15″	.991 801	.981 528	.142 386
24.9°	8° 17′ 14″	.991 735	.981 380	.142 945
25.0°	8° 19′ 14″	.991 669	.981 231	.143 504

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	$o = mL - nD$		$Z = mL - nD$		Δ
		m	n	m	n	
.671 003	.337 289	.028 976	.004 40	.498 043	.024 97	20.0°
.671 047	.337 329	.029 119	.004 45	.498 023	.025 09	20.1°
.671 091	.337 369	.029 263	.004 49	.498 004	.025 21	20.2°
.671 136	.337 410	.029 407	.004 53	.497 984	.025 33	20.3°
.671 180	.337 451	.029 550	.004 58	.497 964	.025 45	20.4°
.671 225	.337 492	.029 694	.004 62	.497 944	.025 57	20.5°
.671 270	.337 533	.029 838	.004 67	.497 924	.025 68	20.6°
.671 316	.337 574	.029 981	.004 71	.497 904	.025 80	20.7°
.671 361	.337 616	.030 125	.004 76	.497 884	.025 92	20.8°
.671 407	.337 658	.030 269	.004 80	.497 863	.026 04	20.9°
.671 453	.337 700	.030 412	.004 85	.497 843	.026 16	21.0°
.671 499	.337 742	.030 556	.004 89	.497 822	.026 28	21.1°
.671 546	.337 785	.030 699	.004 94	.497 802	.026 40	21.2°
.671 593	.337 827	.030 843	.004 99	.497 781	.026 52	21.3°
.671 640	.337 870	.030 986	.005 03	.497 760	.026 64	21.4°
.671 687	.337 913	.031 130	.005 08	.497 739	.026 75	21.5°
.671 734	.337 957	.031 273	.005 13	.497 718	.026 87	21.6°
.671 782	.338 000	.031 417	.005 17	.497 697	.026 99	21.7°
.671 830	.338 044	.031 560	.005 22	.497 676	.027 11	21.8°
.671 878	.338 088	.031 704	.005 27	.497 655	.027 23	21.9°
.671 926	.338 132	.031 847	.005 32	.497 633	.027 35	22.0°
.671 975	.338 177	.031 990	.005 36	.497 612	.027 46	22.1°
.672 024	.338 221	.032 134	.005 41	.497 590	.027 58	22.2°
.672 073	.338 266	.032 277	.005 46	.497 568	.027 70	22.3°
.672 122	.338 311	.032 421	.005 51	.497 547	.027 82	22.4°
.672 172	.338 356	.032 564	.005 56	.497 525	.027 94	22.5°
.672 221	.338 402	.032 707	.005 61	.497 503	.028 05	22.6°
.672 271	.338 448	.032 850	.005 65	.497 481	.028 17	22.7°
.672 322	.338 494	.032 994	.005 70	.497 458	.028 29	22.8°
.672 372	.338 540	.033 137	.005 75	.497 436	.028 41	22.9°
.672 423	.338 586	.033 280	.005 80	.497 414	.028 52	23.0°
.672 474	.338 633	.033 423	.005 85	.497 391	.028 64	23.1°
.672 525	.338 679	.033 567	.005 90	.497 369	.028 76	23.2°
.672 576	.338 726	.033 710	.005 95	.497 346	.028 87	23.3°
.672 628	.338 774	.033 853	.006 00	.497 323	.028 99	23.4°
.672 680	.338 821	.033 996	.006 05	.497 300	.029 11	23.5°
.672 732	.338 869	.034 139	.006 11	.497 277	.029 23	23.6°
.672 784	.338 917	.034 282	.006 16	.497 254	.029 34	23.7°
.672 837	.338 965	.034 425	.006 21	.497 231	.029 46	23.8°
.672 890	.339 013	.034 568	.006 26	.497 208	.029 58	23.9°
.672 943	.339 061	.034 711	.006 31	.497 185	.029 69	24.0°
.672 996	.339 110	.034 854	.006 36	.497 161	.029 81	24.1°
.673 050	.339 159	.034 997	.006 42	.497 138	.029 92	24.2°
.673 103	.339 208	.035 140	.006 47	.497 114	.030 04	24.3°
.673 157	.339 258	.035 283	.006 52	.497 090	.030 16	24.4°
.673 212	.339 307	.035 426	.006 57	.497 067	.030 27	24.5°
.673 266	.339 357	.035 569	.006 63	.497 043	.030 39	24.6°
.673 321	.339 407	.035 712	.006 68	.497 019	.030 50	24.7°
.673 376	.339 457	.035 855	.006 73	.496 995	.030 62	24.8°
.673 431	.339 508	.035 998	.006 79	.496 970	.030 74	24.9°
.673 486	.339 559	.036 140	.006 84	.496 946	.030 85	25.0°

Δ	A	$\frac{C}{L}$	$\frac{X}{L}$	$\frac{Y}{L}$
25.0°	8° 19′ 14″	.991 669	.981 231	.143 504
25.1°	8° 21′ 13″	.991 602	.981 082	.144 062
25.2°	8° 23′ 12″	.991 536	.980 932	.144 620
25.3°	8° 25′ 12″	.991 468	.980 782	.145 179
25.4°	8° 27′ 11″	.991 401	.980 631	.145 737
25.5°	8° 29′ 11″	.991 333	.980 479	.146 294
25.6°	8° 31′ 10″	.991 266	.980 327	.146 852
25.7°	8° 33′ 10″	.991 197	.980 175	.147 409
25.8°	8° 35′ 09″	.991 129	.980 022	.147 966
25.9°	8° 37′ 08″	.991 060	.979 868	.148 523
26.0°	8° 39′ 08″	.990 991	.979 714	.149 080
26.1°	8° 41′ 07″	.990 922	.979 559	.149 637
26.2°	8° 43′ 07″	.990 853	.979 403	.150 193
26.3°	8° 45′ 06″	.990 783	.979 247	.150 750
26.4°	8° 47′ 05″	.990 713	.979 091	.151 306
26.5°	8° 49′ 05″	.990 642	.978 933	.151 861
26.6°	8° 51′ 04″	.990 572	.978 776	.152 417
26.7°	8° 53′ 03″	.990 501	.978 617	.152 973
26.8°	8° 55′ 03″	.990 430	.978 458	.153 528
26.9°	8° 57′ 02″	.990 359	.978 299	.154 083
27.0°	8° 59′ 02″	.990 287	.978 139	.154 638
27.1°	9° 01′ 01″	.990 215	.977 978	.155 193
27.2°	9° 03′ 00″	.990 143	.977 817	.155 747
27.3°	9° 05′ 00″	.990 071	.977 655	.156 301
27.4°	9° 06′ 59″	.989 998	.977 493	.156 855
27.5°	9° 08′ 58″	.989 925	.977 330	.157 409
27.6°	9° 10′ 58″	.989 852	.977 167	.157 963
27.7°	9° 12′ 57″	.989 779	.977 003	.158 516
27.8°	9° 14′ 56″	.989 705	.976 838	.159 070
27.9°	9° 16′ 55″	.989 631	.976 673	.159 623
28.0°	9° 18′ 55″	.989 557	.976 507	.160 176
28.1°	9° 20′ 54″	.989 482	.976 341	.160 728
28.2°	9° 22′ 53″	.989 408	.976 174	.161 281
28.3°	9° 24′ 53″	.989 333	.976 007	.161 833
28.4°	9° 26′ 52″	.989 257	.975 839	.162 385
28.5°	9° 28′ 51″	.989 182	.975 670	.162 937
28.6°	9° 30′ 51″	.989 106	.975 501	.163 489
28.7°	9° 32′ 50″	.989 030	.975 331	.164 040
28.8°	9° 34′ 49″	.988 954	.975 161	.164 591
28.9°	9° 36′ 48″	.988 877	.974 990	.165 142
29.0°	9° 38′ 48″	.988 800	.974 819	.165 693
29.1°	9° 40′ 47″	.988 723	.974 647	.166 244
29.2°	9° 42′ 46″	.988 646	.974 475	.166 794
29.3°	9° 44′ 45″	.988 568	.974 302	.167 344
29.4°	9° 46′ 45″	.988 491	.974 128	.167 894
29.5°	9° 48′ 44″	.988 412	.973 954	.168 444
29.6°	9° 50′ 43″	.988 334	.973 779	.168 993
29.7°	9° 52′ 42″	.988 255	.973 604	.169 543
29.8°	9° 54′ 41″	.988 177	.973 428	.170 092
29.9°	9° 56′ 41″	.988 097	.973 251	.170 641
30.0°	9° 58′ 40″	988 018	.973 074	.171 189

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

U/L	V/L	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.673 486	.339 559	.036 140	.006 84	.496 946	.030 85	25.0°
.673 542	.339 610	.036 283	.006 89	.496 922	.030 97	25.1°
.673 598	.339 661	.036 426	.006 95	.496 897	.031 08	25.2°
.673 654	.339 712	.036 569	.007 00	.496 873	.031 20	25.3°
.673 710	.339 764	.036 711	.007 06	.496 848	.031 31	25.4°
.673 767	.339 815	.036 854	.007 11	.496 823	.031 43	25.5°
.673 824	.339 867	.036 997	.007 17	.496 798	.031 54	25.6°
.673 881	.339 920	.037 139	.007 22	.496 773	.031 66	25.7°
.673 938	.339 972	.037 282	.007 28	.496 748	.031 77	25.8°
.673 996	.340 025	.037 425	.007 33	.496 723	.031 89	25.9°
.674 054	.340 078	.037 567	.007 39	.496 698	.032 00	26.0°
.674 112	.340 131	.037 710	.007 44	.496 673	.032 12	26.1°
.674 170	.340 184	.037 852	.007 50	.496 647	.032 23	26.2°
.674 229	.340 238	.037 995	.007 56	.496 622	.032 34	26.3°
.674 287	.340 292	.038 138	.007 61	.496 596	.032 46	26.4°
.674 346	.340 346	.038 280	.007 67	.496 570	.032 57	26.5°
.674 406	.340 400	.038 422	.007 73	.496 544	.032 69	26.6°
.674 465	.340 454	.038 565	.007 78	.496 518	.032 80	26.7°
.674 525	.340 509	.038 707	.007 84	.496 492	.032 91	26.8°
.674 585	.340 564	.038 850	.007 90	.496 466	.033 03	26.9°
.674 645	.340 619	.038 992	.007 96	.496 440	.033 14	27.0°
.674 706	.340 674	.039 135	.008 01	.496 414	.033 25	27.1°
.674 766	.340 730	.039 277	.008 07	.496 387	.033 37	27.2°
.674 827	.340 786	.039 419	.008 13	.496 361	.033 48	27.3°
.674 888	.340 842	.039 561	.008 19	.496 334	.033 59	27.4°
.674 950	.340 898	.039 704	.008 25	.496 308	.033 71	27.5°
.675 012	.340 955	.039 846	.008 31	.496 281	.033 82	27.6°
.675 074	.341 011	.039 988	.008 37	.496 254	.033 93	27.7°
.675 136	.341 068	.040 130	.008 43	.496 227	.034 05	27.8°
.675 198	.341 125	.040 273	.008 49	.496 200	.034 16	27.9°
.675 261	.341 183	.040 415	.008 54	.496 173	.034 27	28.0°
.675 324	.341 240	.040 557	.008 60	.496 145	.034 38	28.1°
.675 387	.341 298	.040 699	.008 66	.496 118	.034 50	28.2°
.675 450	.341 356	.040 841	.008 73	.496 091	.034 61	28.3°
.675 514	.341 415	.040 983	.008 79	.496 063	.034 72	28.4°
.675 578	.341 473	.041 125	.008 85	.496 036	.034 83	28.5°
.675 642	.341 532	.041 267	.008 91	.496 008	.034 94	28.6°
.675 706	.341 591	.041 409	.008 97	.495 980	.035 06	28.7°
.675 771	.341 650	.041 551	.009 03	.495 952	.035 17	28.8°
.675 836	.341 710	.041 693	.009 09	.495 924	.035 28	28.9°
.675 901	.341 769	.041 835	.009 15	.495 896	.035 39	29.0°
.675 966	.341 829	.041 977	.009 21	.495 868	.035 50	29.1°
.676 032	.341 889	.042 119	.009 28	.495 839	.035 61	29.2°
.676 098	.341 950	.042 261	.009 34	.495 811	.035 72	29.3°
.676 164	.342 010	.042 402	.009 40	.495 782	.035 84	29.4°
.676 230	.342 071	.042 544	.009 46	.495 754	.035 95	29.5°
.676 297	.342 132	.042 686	.009 53	.495 725	.036 06	29.6°
.676 364	.342 193	.042 828	.009 59	.495 696	.036 17	29.7°
.676 431	.342 255	.042 970	.009 65	.495 668	.036 28	29.8°
.676 498	.342 316	.043 111	.009 72	.495 639	.036 39	29.9°
.676 566	.342 378	.043 253	.009 78	.495 610	.036 50	30.0°

Δ	A	$\frac{C}{L}$	$\frac{X}{L}$	$\frac{Y}{L}$
30.0°	9° 58′ 40″	.988 018	.973 074	.171 189
30.1°	10° 00′ 39″	.987 938	.972 897	.171 738
30.2°	10° 02′ 38″	.987 858	.972 719	.172 286
30.3°	10° 04′ 37″	.987 778	.972 540	.172 834
30.4°	10° 06′ 37″	.987 698	.972 361	.173 382
30.5°	10° 08′ 36″	.987 617	.972 181	.173 929
30.6°	10° 10′ 35″	.987 536	.972 000	.174 477
30.7°	10° 12′ 34″	.987 455	.971 820	.175 024
30.8°	10° 14′ 33″	.987 373	.971 638	.175 571
30.9°	10° 16′ 32″	.987 291	.971 456	.176 117
31.0°	10° 18′ 32″	.987 209	.971 273	.176 664
31.1°	10° 20′ 31″	.987 127	.971 090	.177 210
31.2°	10° 22′ 30″	.987 044	.970 907	.177 756
31.3°	10° 24′ 29″	.986 962	.970 722	.178 302
31.4°	10° 26′ 28″	.986 879	.970 537	.178 847
31.5°	10° 28′ 27″	.986 795	.970 352	.179 392
31.6°	10° 30′ 26″	.986 712	.970 166	.179 938
31.7°	10° 32′ 25″	.986 628	.969 980	.180 482
31.8°	10° 34′ 24″	.986 544	.969 792	.181 027
31.9°	10° 36′ 24″	.986 459	.969 605	.181 571
32.0°	10° 38′ 23″	.986 375	.969 417	.182 116
32.1°	10° 40′ 22″	.986 290	.969 228	.182 659
32.2°	10° 42′ 21″	.986 205	.969 039	.183 203
32.3°	10° 44′ 20″	.986 119	.968 849	.183 747
32.4°	10° 46′ 19″	.986 033	.968 658	.184 290
32.5°	10° 48′ 18″	.985 948	.968 467	.184 833
32.6°	10° 50′ 17″	.985 861	.968 276	.185 376
32.7°	10° 52′ 16″	.985 775	.968 084	.185 918
32.8°	10° 54′ 15″	.985 688	.967 891	.186 460
32.9°	10° 56′ 14″	.985 601	.967 698	.187 002
33.0°	10° 58′ 13″	.985 514	.967 504	.187 544
33.1°	11° 00′ 12″	.985 426	.967 310	.188 086
33.2°	11° 02′ 11″	.985 339	.967 115	.188 627
33.3°	11° 04′ 10″	.985 251	.966 920	.189 168
33.4°	11° 06′ 09″	.985 162	.966 724	.189 709
33.5°	11° 08′ 08″	.985 074	.966 528	.190 250
33.6°	11° 10′ 07″	.984 985	.966 331	.190 790
33.7°	11° 12′ 06″	.984 896	.966 133	.191 330
33.8°	11° 14′ 05″	.984 807	.965 935	.191 870
33.9°	11° 16′ 04″	.984 717	.965 736	.192 410
34.0°	11° 18′ 03″	.984 627	.965 537	.192 949
34.1°	11° 20′ 02″	.984 537	.965 337	.193 488
34.2°	11° 22′ 01″	.984 447	.965 137	.194 027
34.3°	11° 24′ 00″	.984 356	.964 936	.194 566
34.4°	11° 25′ 59″	.984 265	.964 735	.195 104
34.5°	11° 27′ 58″	.984 174	.964 533	.195 643
34.6°	11° 29′ 57″	.984 083	.964 330	.196 180
34.7°	11° 31′ 56″	.983 991	.964 127	.196 718
34.8°	11° 33′ 55″	.983 899	.963 923	.197 256
34.9°	11° 35′ 54″	.983 807	.963 719	.197 793
35.0°	11° 37′ 53″	.983 715	.963 515	.198 330

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.676 566	.342 378	.043 253	.009 78	.495 610	.036 50	30.0°
.676 634	.342 441	.043 395	.009 84	.495 580	.036 61	30.1°
.676 702	.342 503	.043 536	.009 91	.495 551	.036 72	30.2°
.676 770	.342 566	.043 678	.009 97	.495 522	.036 83	30.3°
.676 839	.342 629	.043 819	.010 04	.495 492	.036 94	30.4°
.676 908	.342 692	.043 961	.010 10	.495 463	.037 05	30.5°
.676 977	.342 755	.044 102	.010 17	.495 433	.037 16	30.6°
.677 046	.342 819	.044 244	.010 23	.495 403	.037 27	30.7°
.677 116	.342 882	.044 385	.010 30	.495 374	.037 38	30.8°
.677 186	.342 947	.044 527	.010 36	.495 344	.037 49	30.9°
.677 256	.343 011	.044 668	.010 43	.495 314	.037 60	31.0°
.677 326	.343 075	.044 810	.010 49	.495 284	.037 71	31.1°
.677 397	.343 140	.044 951	.010 56	.495 253	.037 82	31.2°
.677 468	.343 205	.045 092	.010 62	.495 223	.037 92	31.3°
677 539	.343 270	.045 234	.010 69	.495 193	.038 03	31.4°
.677 610	.343 336	.045 375	.010 76	.495 162	.038 14	31.5°
.677 682	.343 401	.045 516	.010 82	.495 132	.038 25	31.6°
.677 754	.343 467	.045 658	.010 89	.495 101	.038 36	31.7°
.677 826	.343 534	.045 799	.010 96	.495 070	.038 47	31.8°
.677 898	.343 600	.045 940	.011 03	.495 039	.038 58	31.9°
.677 971	.343 667	.046 081	.011 09	.495 008	.038 68	32.0°
.678 044	.343 733	.046 222	.011 16	.494 977	.038 79	32.1°
.678 117	.343 801	046 363	.011 23	.494 946	.038 90	32.2°
.678 190	.343 868	046 504	.011 30	.494 915	.039 01	32.3°
.678 264	.343 936	.046 646	.011 36	.494 884	.039 12	32.4°
.678 338	.344 003	.046 787	.011 43	.494 852	.039 22	32.5°
.678 412	.344 071	.046 928	.011 50	.494 821	.039 33	32.6°
678 487	.344 140	.047 069	.011 57	.494 789	.039 44	32.7°
678 561	.344 208	.047 210	.011 64	.494 757	.039 54	32.8°
.678 636	.344 277	.047 350	.011 71	.494 725	.039 65	32.9°
.678 712	.344 346	.047 491	.011 78	.494 694	.039 76	33.0°
678 787	.344 415	.047 632	.011 85	.494 662	.039 87	33.1°
678 863	.344 485	.047 773	.011 92	.494 629	.039 97	33.2°
678 939	.344 555	.047 914	.011 99	.494 597	.040 08	33.3°
.679 015	.344 625	.048 055	.012 06	.494 565	.040 19	33.4°
679 092	.344 695	.048 195	.012 13	.494 533	.040 29	33.5°
.679 168	.344 765	.048 336	.012 20	.494 500	.040 40	33.6°
.679 245	.344 836	048 477	.012 27	.494 468	.040 50	33.7°
.679 323	.344 907	.048 618	.012 34	.494 435	.040 61	33.8°
.679 400	.344 978	.048 758	.012 41	.494 402	.040 72	33.9°
.679 478	.345 049	.048 899	.012 48	.494 369	.040 82	34.0°
.679 556	.345 121	.049 039	.012 55	.494 336	.040 93	34.1°
.679 634	.345 193	.049 180	.012 62	.494 303	.041 03	34.2°
.679 713	.345 265	.049 321	.012 69	.494 270	.041 14	34.3°
.679 792	.345 338	.049 461	.012 77	.494 237	.041 24	34.4°
.679 871	.345 410	.049 602	.012 84	.494 204	.041 35	34.5°
.679 950	.345 483	.049 742	.012 91	.494 170	.041 45	34.6°
.680 030	.345 556	.049 882	.012 98	.494 137	.041 56	34.7°
.680 110	.345 630	.050 023	.013 06	.494 103	.041 66	34.8°
.680 190	.345 703	.050 163	.013 13	.494 070	.041 77	34.9°
.680 270	.345 777	.050 304	.013 20	.494 036	.041 87	35.0°

Δ	A	$\frac{C}{L}$	$\frac{X}{L}$	$\frac{Y}{L}$
35.0°	11° 37′ 53″	.983 715	.963 515	.198 330
35.1°	11° 39′ 52″	.983 622	.963 309	.198 866
35.2°	11° 41′ 50″	.983 529	.963 103	.199 403
35.3°	11° 43′ 49″	.983 436	.962 897	.199 939
35.4°	11° 45′ 48″	.983 343	.962 690	.200 475
35.5°	11° 47′ 47″	.983 249	.962 483	.201 010
35.6°	11° 49′ 46″	.983 155	.962 275	.201 546
35.7°	11° 51′ 45″	.983 061	.962 066	.202 081
35.8°	11° 53′ 44″	.982 966	.961 857	.202 616
35.9°	11° 55′ 43″	.982 872	.961 648	.203 151
36.0°	11° 57′ 41″	.982 777	.961 438	.203 685
36.1°	11° 59′ 40″	.982 681	.961 227	.204 219
36.2°	12° 01′ 39″	.982 586	.961 016	.204 753
36.3°	12° 03′ 38″	.982 490	.960 804	.205 286
36.4°	12° 05′ 37″	.982 394	.960 592	.205 820
36.5°	12° 07′ 36″	.982 298	.960 379	.206 353
36.6°	12° 09′ 34″	.982 201	.960 165	.206 886
36.7°	12° 11′ 33″	.982 104	.959 951	.207 418
36.8°	12° 13′ 32″	.982 007	.959 737	.207 951
36.9°	12° 15′ 31″	.981 910	.959 522	.208 483
37.0°	12° 17′ 30″	.981 812	.959 306	.209 014
37.1°	12° 19′ 28″	.981 715	.959 090	.209 546
37.2°	12° 21′ 27″	.981 617	.958 874	.210 077
37.3°	12° 23′ 26″	.981 518	.958 657	.210 608
37.4°	12° 25′ 25″	.981 420	.958 439	.211 139
37.5°	12° 27′ 23″	.981 321	.958 221	.211 669
37.6°	12° 29′ 22″	.981 222	.958 002	.212 199
37.7°	12° 31′ 21″	.981 122	.957 783	.212 729
37.8°	12° 33′ 20″	.981 023	.957 563	.213 259
37.9°	12° 35′ 18″	.980 923	.957 342	.213 788
38.0°	12° 37′ 17″	.980 823	.957 121	.214 317
38.1°	12° 39′ 16″	.980 722	.956 900	.214 846
38.2°	12° 41′ 14″	.980 622	.956 678	.215 375
38.3°	12° 43′ 13″	.980 521	.956 455	.215 903
38.4°	12° 45′ 12″	.980 420	.956 232	.216 431
38.5°	12° 47′ 11″	.980 318	.956 009	.216 959
38.6°	12° 49′ 09″	.980 217	.955 785	.217 486
38.7°	12° 51′ 08″	.980 115	.955 560	.218 013
38.8°	12° 53′ 07″	.980 012	.955 335	.218 540
38.9°	12° 55′ 05″	.979 910	.955 109	.219 067
39.0°	12° 57′ 04″	.979 807	.954 883	.219 593
39.1°	12° 59′ 02″	.979 704	.954 656	.220 119
39.2°	13° 01′ 01″	.979 601	.954 429	.220 645
39.3°	13° 03′ 00″	.979 498	.954 201	.221 171
39.4°	13° 04′ 58″	.979 394	.953 973	.221 696
39.5°	13° 06′ 57″	.979 290	.953 744	.222 221
39.6°	13° 08′ 56″	.979 186	.953 514	.222 745
39.7°	13° 10′ 54″	.979 081	.953 284	.223 270
39.8°	13° 12′ 53″	.978 977	.953 054	.223 794
39.9°	13° 14′ 51″	.978 872	.952 823	.224 318
40.0°	13° 16′ 50″	.978 766	.952 591	.224 841

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	o = mL — nD		Z = mL — nD		Δ
		m	n	m	n	
.680 270	.345 777	.050 304	.013 20	.494 036	.041 87	35.0°
.680 351	.345 851	.050 444	.013 28	.494 002	.041 98	35.1°
.680 432	.345 926	.050 584	.013 35	.493 968	.042 08	35.2°
.680 513	.346 000	.050 724	.013 42	.493 934	.042 18	35.3°
.680 595	.346 075	.050 865	.013 50	.493 900	.042 29	35.4°
.680 677	.346 150	.051 005	.013 57	.493 866	.042 39	35.5°
.680 759	.346 226	.051 145	.013 64	.493 831	.042 49	35.6°
.680 841	.346 301	.051 285	.013 72	.493 797	.042 60	35.7°
.680 923	.346 377	.051 425	.013 79	.493 762	.042 70	35.8°
.681 006	.346 453	.051 565	.013 87	.493 728	.042 81	35.9°
.681 089	.346 529	.051 705	.013 94	.493 693	.042 91	36.0°
.681 173	.346 606	.051 845	.014 02	.493 658	.043 01	36.1°
.681 256	.346 683	.051 985	.014 09	.493 623	.043 11	36.2°
.681 340	.346 760	.052 125	.014 17	.493 588	.043 22	36.3°
.681 424	.346 837	.052 265	.014 24	.493 553	.043 32	36.4°
.681 509	.346 915	.052 405	.014 32	.493 518	.043 42	36.5°
.681 594	.346 993	.052 545	.014 39	.493 483	.043 52	36.6°
.681 679	.347 071	.052 685	.014 47	.493 447	.043 63	36.7°
.681 764	.347 149	.052 825	.014 55	.493 412	.043 73	36.8°
.681 849	.347 228	.052 965	.014 62	.493 376	.043 83	36.9°
.681 935	.347 307	.053 104	.014 70	.493 341	.043 93	37.0°
.682 021	.347 386	.053 244	.014 78	.493 305	.044 03	37.1°
.682 107	.347 465	.053 384	.014 85	.493 269	.044 14	37.2°
.682 194	.347 545	.053 523	.014 93	.493 233	.044 24	37.3°
.682 281	.347 625	.053 663	.015 01	.493 197	.044 34	37.4°
.682 368	.347 705	.053 803	.015 09	.493 161	.044 44	37.5°
.682 455	.347 785	.053 942	.015 16	.493 125	.044 54	37.6°
.682 543	.347 866	.054 082	.015 24	.493 089	.044 64	37.7°
.682 631	.347 947	.054 221	.015 32	.493 052	.044 74	37.8°
.682 719	.348 028	.054 361	.015 40	.493 016	.044 84	37.9°
.682 808	.348 109	.054 500	.015 48	.492 979	.044 94	38.0°
.682 896	.348 191	.054 640	.015 55	.492 943	.045 04	38.1°
.682 986	.348 273	.054 779	.015 63	.492 906	.045 14	38.2°
.683 075	.348 355	.054 919	.015 71	.492 869	.045 24	38.3°
.683 164	.384 437	.055 058	.015 79	.492 832	.045 34	38.4°
.683 254	.348 520	.055 197	.015 87	.492 795	.045 44	38.5°
.683 344	.348 603	.055 336	.015 95	.492 758	.045 54	38.6°
.683 435	.348 686	.055 476	.016 03	.492 721	.045 64	38.7°
.683 526	.348 769	.055 615	.016 11	.492 683	.045 74	38.8°
.683 617	.348 853	.055 754	.016 19	.492 646	.045 84	38.9°
.683 708	.348 937	.055 893	.016 27	.492 608	.045 94	39.0°
.683 799	.349 021	.056 032	.016 35	.492 571	.046 04	39.1°
.683 891	.349 106	.056 171	.016 43	.492 533	.046 14	39.2°
.683 983	.349 190	.056 310	.016 51	.492 495	.046 24	39.3°
.684 076	.349 275	.056 450	.016 59	.492 458	.046 34	39.4°
.684 168	.349 361	.056 589	.016 67	.492 420	.046 43	39.5°
.684 261	.349 446	.056 727	.016 75	.492 382	.046 53	39.6°
.684 354	.349 532	.056 866	.016 83	.492 343	.046 63	39.7°
.684 448	.349 618	.057 005	.016 92	.492 305	.046 73	39.8°
.684 542	.349 704	.057 144	.017 00	.492 267	.046 83	39.9°
.684 636	.349 791	.057 283	.017 08	.492 229	.046 92	40.0°

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL—Cont'd.

Δ	A	$\frac{C}{L}$	$\frac{X}{L}$	$\frac{Y}{L}$
40.0°	13° 16′ 50″	.978 766	.952 591	.224 841
40.1°	13° 18′ 48″	.978 661	.952 359	.225 365
40.2°	13° 20′ 47″	.978 555	.952 127	.225 888
40.3°	13° 22′ 46″	.978 449	.951 893	.226 410
40.4°	13° 24′ 44″	.978 343	.951 660	.226 933
40.5°	13° 26′ 43″	.978 236	.951 426	.227 455
40.6°	13° 28′ 41″	.978 130	.951 191	.227 977
40.7°	13° 30′ 40″	.978 023	.950 956	.228 498
40.8°	13° 32′ 38″	.977 915	.950 720	.229 019
40.9°	13° 34′ 37″	.977 808	.950 484	.229 540
41.0°	13° 36′ 35″	.977 700	.950 247	.230 061
41.1°	13° 38′ 34″	.977 592	.950 010	.230 581
41.2°	13° 40′ 32″	.977 484	.949 772	.231 102
41.3°	13° 42′ 31″	.977 375	.949 533	.231 621
41.4°	13° 44′ 29″	.977 266	.949 294	.232 141
41.5°	13° 46′ 28″	.977 157	.949 055	.232 660
41.6°	13° 48′ 26″	.977 048	.948 815	.233 179
41.7°	13° 50′ 25″	.976 938	.948 575	.233 698
41.8°	13° 52′ 23″	.976 828	.948 334	.234 216
41.9°	13° 54′ 22″	.976 718	.948 092	.234 734
42.0°	13° 56′ 20″	.976 608	.947 850	.235 252
42.1°	13° 58′ 18″	.976 497	.947 608	.235 769
42.2°	14° 00′ 17″	.976 387	.947 365	.236 286
42.3°	14° 02′ 15″	.976 276	.947 121	.236 803
42.4°	14° 04′ 14″	.976 164	.946 877	.237 320
42.5°	14° 06′ 12″	.976 053	.946 632	.237 836
42.6°	14° 08′ 10″	.975 941	.946 387	.238 352
42.7°	14° 10′ 09″	.975 829	.946 142	.238 868
42.8°	14° 12′ 07″	.975 716	.945 895	.239 383
42.9°	14° 14′ 06″	.975 604	.945 649	.239 898
43.0°	14° 16′ 04″	.975 491	.945 401	.240 413
43.1°	14° 18′ 02″	.975 378	.945 154	.240 927
43.2°	14° 20′ 01″	.975 264	.944 906	.241 442
43.3°	14° 21′ 59″	.975 151	.944 657	.241 956
43.4°	14° 23′ 57″	.975 037	.944 408	.242 469
43.5°	14° 25′ 56″	.974 923	.944 158	.242 982
43.6°	14° 27′ 54″	.974 808	.943 908	.243 495
43.7°	14° 29′ 52″	.974 694	.943 657	.244 008
43.8°	14° 31′ 50″	.974 579	.943 405	.244 520
43.9°	14° 33′ 49″	.974 464	.943 154	.245 032
44.0°	14° 35′ 47″	.974 348	.942 901	.245 544
44.1°	14° 37′ 45″	.974 233	.942 648	.246 055
44.2°	14° 39′ 44″	.974 117	.942 395	.246 566
44.3°	14° 41′ 42″	.974 001	.942 141	.247 077
44.4°	14° 43′ 40″	.973 884	.941 887	.247 588
44.5°	14° 45′ 38″	.973 768	.941 632	.248 098
44.6°	14° 47′ 37″	.973 651	.941 377	.248 608
44.7°	14° 49′ 35″	.973 534	.941 121	.249 117
44.8°	14° 51′ 33″	.973 416	.940 864	.249 627
44.9°	14° 53′ 31″	.973 299	.940 607	.250 135
45.0°	14° 55′ 29″	.973 181	.940 350	.250 644

TABLE OF FUNCTIONS OF THE TEN-CHORD SPIRAL.—Cont'd.

$\frac{U}{L}$	$\frac{V}{L}$	$o = mL - nD$		$Z = mL - nD$		Δ
		m	n	m	n	
.684 636	.349 791	.057 283	.017 08	.492 229	.046 92	40.0°
.684 730	.349 878	.057 422	.017 16	.492 190	.047 02	40.1°
.684 825	.349 965	.057 561	.017 24	.492 151	.047 12	40.2°
.684 920	.350 052	.057 699	.017 33	.492 113	.047 22	40.3°
.685 015	.350 140	.057 838	.017 41	.492 074	.047 31	40.4°
.685 110	.350 228	.057 977	.017 49	.492 035	.047 41	40.5°
.685 206	.350 316	.058 115	.017 57	.491 996	.047 51	40.6°
.685 302	.350 404	.058 254	.017 66	.491 957	.047 60	40.7°
.685 398	.350 493	.058 393	.017 74	.491 918	.047 70	40.8°
.685 495	.350 582	.058 531	.017 82	.491 879	.047 80	40.9°
.685 592	.350 671	.058 670	.017 91	.491 839	.047 89	41.0°
.685 689	.350 761	.058 808	.017 99	.491 800	.047 99	41.1°
.685 786	.350 851	.058 946	.018 07	.491 760	.048 08	41.2°
.685 884	.350 941	.059 085	.018 16	.491 721	.048 18	41.3°
.685 982	.351 031	.059 223	.018 24	.491 681	.048 28	41.4°
.686 081	.351 121	.059 362	.018 33	.491 641	.048 37	41.5°
.686 179	.351 212	.059 500	.018 41	.491 602	.048 47	41.6°
.686 278	.351 303	.059 638	.018 50	.491 562	.048 56	41.7°
.686 377	.351 395	.059 776	.018 58	.491 521	.048 66	41.8°
.686 477	.351 486	.059 915	.018 67	.491 481	.048 75	41.9°
.686 576	.351 578	.060 053	.018 75	.491 441	.048 85	42.0°
.686 677	.351 671	.060 191	.018 84	.491 401	.048 94	42.1°
.686 777	.351 763	.060 329	.018 92	.491 360	.049 04	42.2°
.686 878	.351 856	.060 467	.019 01	.491 320	.049 13	42.3°
.686 978	.351 949	.060 605	.019 09	.491 279	.049 22	42.4°
.687 080	.352 042	.060 743	.019 18	.491 239	.049 32	42.5°
.687 181	.352 136	.060 881	.019 26	.491 198	.049 41	42.6°
.687 283	.352 229	.061 019	.019 35	.491 157	.049 51	42.7°
.687 385	.352 324	.061 157	.019 44	.491 116	.049 60	42.8°
.687 487	.352 418	.061 295	.019 52	.491 075	.049 69	42.9°
.687 590	.352 513	.061 433	.019 61	.491 034	.049 79	43.0°
.687 693	.352 608	.061 571	.019 70	.490 992	.049 88	43.1°
.687 796	.352 703	.061 708	.019 79	.490 951	.049 97	43.2°
.687 900	.352 798	.061 846	.019 87	.490 910	.050 06	43.3°
.688 004	.352 894	.061 984	.019 96	.490 868	.050 16	43.4°
.688 108	.352 990	.062 122	.020 05	.490 827	.050 25	43.5°
.688 212	.353 086	.062 259	.020 14	.490 785	.050 34	43.6°
.688 317	.353 183	.062 397	.020 22	.490 743	.050 43	43.7°
.688 422	.353 280	.062 534	.020 31	.490 701	.050 53	43.8°
.688 527	.353 377	.062 672	.020 40	.490 659	.050 62	43.9°
.688 633	.353 474	.062 809	.020 49	.490 617	.050 71	44.0°
.688 739	.353 572	.062 947	.020 58	.490 575	.050 80	44.1°
.688 845	.353 670	.063 084	.020 67	.490 533	.050 89	44.2°
.688 952	.353 768	.063 222	.020 75	.490 491	.050 98	44.3°
.689 059	.353 867	.063 359	.020 84	.490 448	.051 08	44.4°
.689 166	.353 966	.063 496	.020 93	.490 406	.051 17	44.5°
.689 273	.354 065	.063 634	.021 02	.490 363	.051 26	44.6°
.689 381	.354 164	.063 771	.021 11	.490 320	.051 35	44.7°
.689 489	.354 264	.063 908	.021 20	.490 278	.051 44	44.8°
.689 597	.354 364	.064 045	.021 29	.490 235	.051 53	44.9°
.689 706	.354 464	.064 182	.021 38	.490 192	.051 62	45.0°

[4]MAINTENANCE OF SURFACE

(a) Elevation of Curves

The approximate formula:

$$E = .00066\ DS^2,$$

in which

E = Elevation in inches of the outer rail at the gage line,
D = Degree of Curve, and
S = Speed in miles per hour,

will give essentially correct theoretical elevations for the outer rail of curves, in which the resultant of forces passes practically through the center line of track.

This formula will give results which are expressed in the following table:

ELEVATION OF OUTER RAIL IN INCHES

Degree of Curve.	Velocity in Miles per Hour													Degree of Curve.
	10	15	20	25	30	35	40	45	50	55	60	65	70	
1	0	⅛	¼	⅜	⅝	¾	1⅛	1⅜	1⅝	2	2⅜	2¾	3¼	1
2	⅛	⅜	½	⅞	1⅛	1⅝	2⅛	2⅝	3¼	4	4¾	5½	6½	2
3	¼	½	¾	1¼	1¾	2⅜	3⅛	4	4⅞	6	7⅛	8⅜	9¾	3
4	¼	⅝	1	1⅝	2⅜	3¼	4¼	5⅜	6⅝	8	9½	......	......	4
5	⅜	¾	1¼	2	3	4	5¼	6⅝	8¼	......	......	......	......	5
6	⅜	1	1⅝	2½	3½	4⅞	6¼	8	......	......	......	......	......	6
7	½	1⅛	1⅞	2⅞	4⅛	5⅝	7⅜	......	......	......	......	......	......	7
8	½	1¼	2⅛	3¼	4¾	6½	8⅜	......	......	......	......	......	......	8
9	⅝	1⅜	2⅜	3¾	5⅜	7¼	......	......	......	......	......	......	......	9
10	¾	1½	2⅝	4⅛	5⅞	8⅛	......	......	......	......	......	......	......	10
11	¾	1¾	2⅞	4½	6½	8⅞	......	......	......	......	......	......	......	11
12	⅞	1⅞	3⅛	4⅞	7⅛	......	......	......	......	......	......	......	......	12
13	⅞	2	3⅜	5⅜	7¾	......	......	......	......	......	......	......	......	13
14	1	2⅛	3⅝	5¾	8⅜	......	......	......	......	......	......	......	......	14
15	1	2¼	3⅞	6¼	8⅞	......	......	......	......	......	......	......	......	15
16	1⅛	2½	4¼	6⅝	......	......	......	......	......	......	......	......	......	16
17	1¼	2⅝	4½	7	......	......	......	......	......	......	......	......	......	17
18	1¼	2¾	4¾	7½	......	......	......	......	......	......	......	......	......	18
19	1⅜	2⅞	5	7¾	......	......	......	......	......	......	......	......	......	19
20	1⅜	3	5¼	8⅛	......	......	......	......	......	......	......	......	......	20

NOTE.—There will be found on page 899, Vol. 30, Proceedings, 1929, a comparison in tabular form of curve elevations for equilibrium speed with "comfortable," "safe," and theoretical "overturning" speeds.

Since the elevation required is a function of the train speed this speed is the first element to be determined.

In general, in determining speed for which a curve shall be elevated, it is necessary to consider traffic which includes moderately slow freight and relatively fast passenger trains. To secure economy in the operation of freight trains and comfort for passenger traffic, the selection of a speed in varying degrees less than the speed of the passenger trains over that particular curve is recommended.

Where easement curves are used the elevation should be attained and run out as prescribed under "Maintenance of Line, (b) Curves; Use of Easement Curves."

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[4] Adopted, Vol. 3, 1902, pp. 56-59, 78-87; Vol. 5, 1904, pp. 528-533, 535, 562, 563; Vol. 6, 1905, pp. 754-757, 759-761; Vol. 11, Part 2, 1910, pp. 935, 944; Vol. 12, Part 1, 1911, pp. 402, 465; Vol. 16, 1915, pp. 732, 1145; Vol. 30, 1929, pp. 895, 1428.

Where easement curves are not used the full elevation should be maintained throughout a simple curve and throughout the sharper curve of a compound curve, if possible, the elevation being attained or run out on the tangent and lighter curve respectively at a rate approximately one inch in a distance in feet equal to 1¾ times the speed in miles per hour.

Ordinarily an elevation of 8 inches should not be exceeded. Speed of trains should be regulated to conform to the maximum elevation used.

The inner rail should be maintained at grade.

(b) Vertical Curves

The use of vertical curves to connect changes in gradient is recommended.

The length should be determined by the gradients to be connected. On Class A roads rates of change of 0.1 per station on summits and 0.05 per station in sags should not be exceeded. On minor roads 0.2 per station on summits and 0.1 per station in sags may be used.

(c) Proper Methods of Tamping

(1) *Earth or Clay Ballast*

Tools.—Shovel equipped with iron cuff or handle; broad-faced tamping bars.

Methods.—Tamp each tie from 18 inches inside of the rail to end of tie with handle of shovel or tamping bar. If possible, tamp the end of the tie outside of rail first and let train pass over before tamping inside of rail; give special attention to tamping under the rail; tamp center of ties loosely with the blade of the shovel; the dirt or clay between the ties should be placed in layers and firmly packed with feet or otherwise, so that it will quickly shed the water; the earth should not be banked above the bottom of the ends of the ties; the filling between the ties should not touch the rail and should be as high as, or higher than, the top of the ties in the middle of the track.

(2) *Cinder Ballast (Railroad Product)*

Tools.—Shovel, tamping bar or tamping pick.

Method.—Same as for gravel.

(3) *Burnt Clay Ballast*

Tools.—Shovel only in soft material. When burnt very hard, tamping pick or bar should be used.

Method.—Tamp 15 inches inside of rail to end of tie, tamping end of tie first, letting train pass before tamping inside of rail; tamp center loosely; tamp well between the ties; dress ballast same as for earth or cinders.

(4) *Broken Stone or Furnace Slag*

Tools.—Shovel, tamping pick, tamping machine, stone forks.

Method.—Tamp 15 inches inside of rail to end of tie; if possible, tamp end of tie outside of rail first and allow train to pass over before tamping inside of rail; tamp well under the rail; tamp well under ties from end of same; do not tamp center of tie; finish in accordance with standard section.

(5) *Chats, Gravel or Chert Ballast*

Tools.—Shovel, tamping pick or tamping bar. For light traffic, shovel tamping is sufficient. For heavy traffic, the tamping pick or tamping bar should be used. The tamping bar is recommended instead of the tamping pick for ordinary practice.

Method.—Tamp solid from a point 15 inches inside of rail to the end of the tie; if possible, tamp the end of the tie outside of the rail first and allow train to pass over before tamping inside of rail; care should be taken not to disturb the old bed. Tie should be tamped solidly from the end, using pick or tamping bar. After train has passed, the center of the tie should be loosely tamped with the blade of the shovel; dress same as stone ballast.

(6) *General*

When not surfacing out of face, as in case of picking up low joints or other low places, the general level of the track should not be disturbed. Where the rails are out of level, but where the difference in elevation is not excessive and is uniform over long stretches of track, a difference in elevation between the two rails of ⅜ inch may be permitted to continue until such time as the track would ordinarily be surfaced out of face.

[5]MAINTENANCE OF GAGE

(a) Appliances and Methods Used to Prevent Spreading of Track and Canting of Rails on Curves

(1) Tie plates are recommended in all cases where economy in maintenance will result from their use.

(2) Shoulder tie plates are recommended in preference to rail braces except for guard rails and stock rails at switches where braces should be used.

(3) For heavy traffic, shoulder tie plates should be used on all ties on curves.

(4) For medium traffic, shoulder tie plates should be used on all ties on curves over three degrees.

(5) For light traffic, where tie plates are not used, the outside of both rails on curves should be double spiked when necessary.

(b) General

(1) The gage (tool) used should be the standard gage recommended.

(2) Within proper limits, a slight variation of gage from the standard is not seriously objectionable, provided the variation is uniform and constant over long distances. Under ordinary conditions it is not necessary to regage track if the increase in gage has not amounted to more than one-half inch, providing such increase is uniform.

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[5] Adopted, Vol. 5, 1904, pp. 534, 535, 563-569; Vol. 6, 1905, pp. 749, 750, 757, 759-761; Vol. 7, 1906, pp. 654, 664; Vol. 10, Part 1, 1909, pp. 398, 400, 467; Vol. 11, Part 2, 1910, pp. 934, 935, 944-946; Vol. 12, Part 1, 1911, pp. 402, 465; Vol. 16, 1915, pp. 732, 1145.

(3) Wide gage, due to worn rail, within the safe limits of wear, need not be corrected until the excess over the gage is equal to ½ inch; it should be corrected by closing in or by interchanging the low and high rails.

(4) Where track is to be spiked to standard gage, the rail should be held against the gage with a bar while the spike is being driven.

(5) Spikes should be started vertically and square, and so driven that the face of the spike shall come in contact with the base of rail; the spike should never have to be straightened while being driven.

(6) The outside spikes of both rails should be near one edge of the tie, and the inside spikes near the other. The inside and outside spikes should be spaced as far apart as the face and character of the tie will permit. The ordinary practice should be to drive the spike 2½ inches from the outer edge of the tie. The old spike holes should be plugged.

GAGES AND FLANGEWAYS IN CURVED TRACK

(See Plans 791, 792, "Portfolio of Trackwork Plans.")

[6]SPEEDS OF TRAINS THROUGH CURVES AND TURNOUTS

Diagrams of speeds of trains through curves and level turnouts are shown in following pages.

Relative Speeds Through Level Turnouts

The following table shows relative speeds through level turnouts, to give the equivalent riding conditions to track elevated three inches less than theoretically required.

TURNOUT		SPEED
Frog Number	Length of Switch	Miles per Hour
4	11	9
5	11	12
6	11	13
7	16.5	17
8-10	16.5	20
11-14	22	27
15	33	37
16-24	33	40

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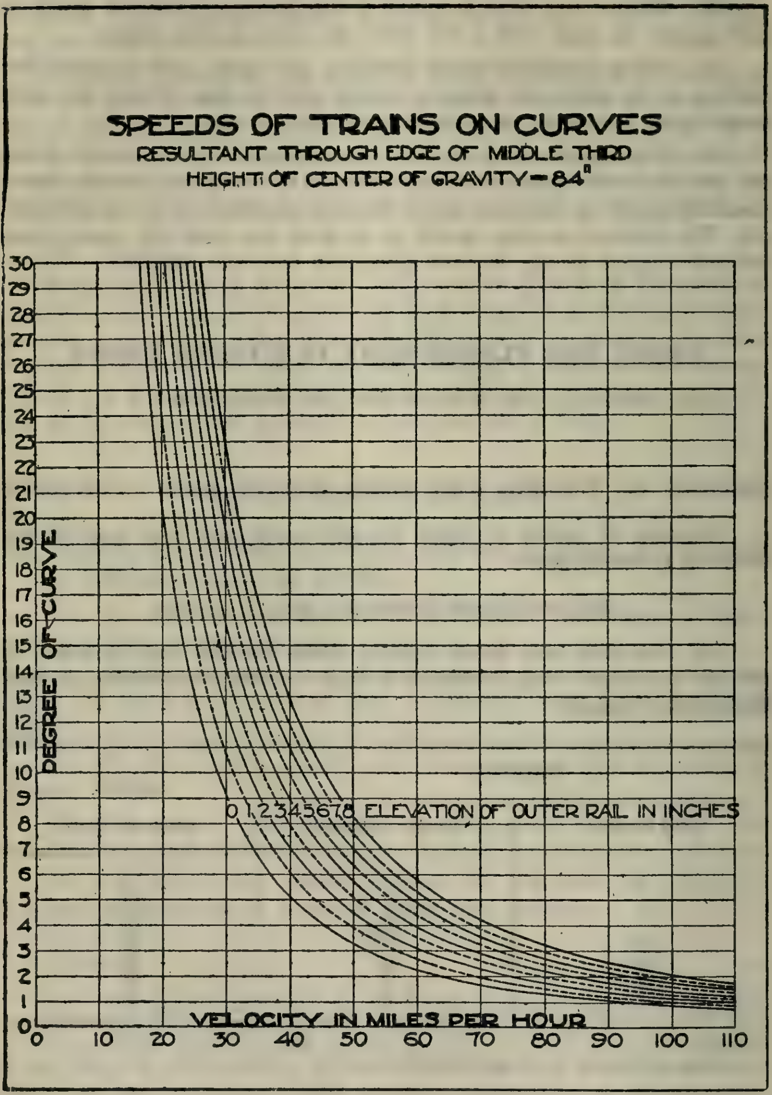
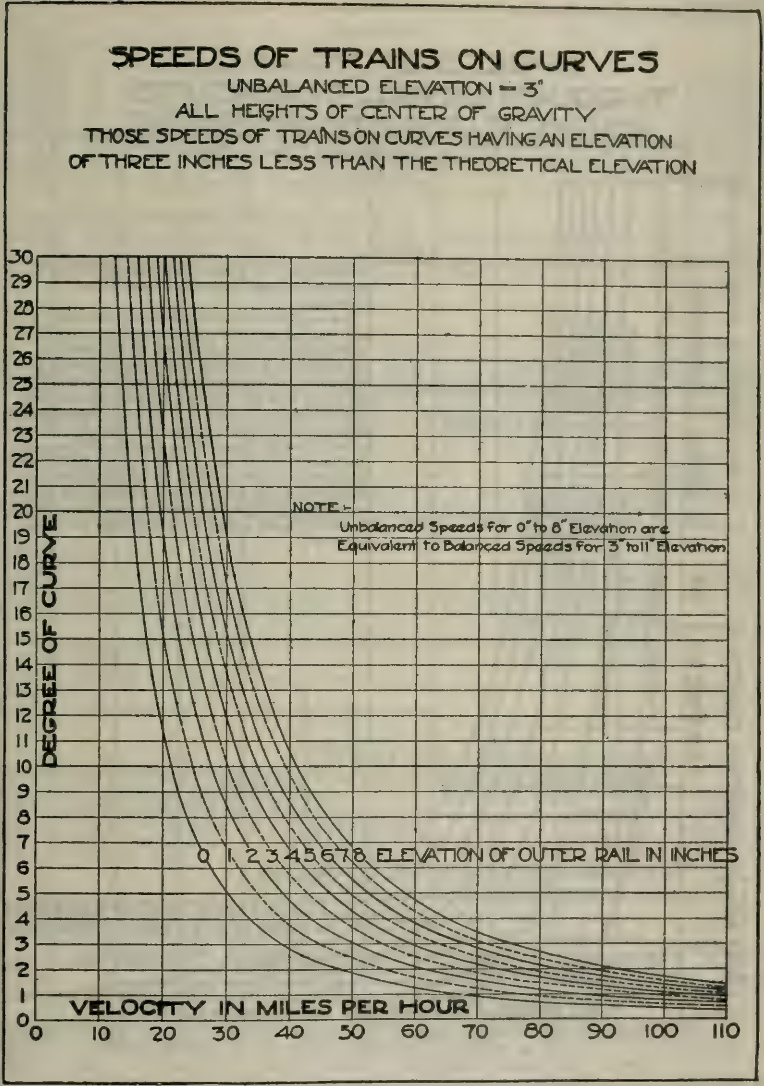
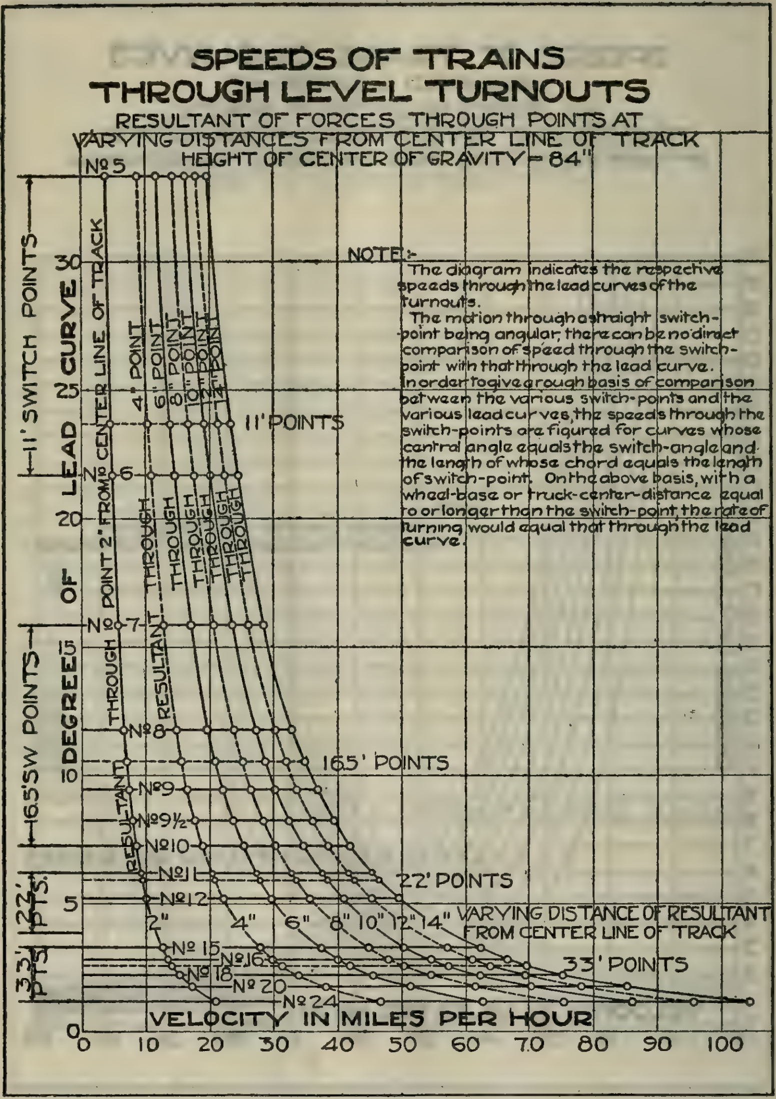
[6] Adopted, Vol. 15, 1914, pp. 594, 1063.


SPEEDS OF TRAINS ON CURVES
RESULTANT THROUGH EDGE OF MIDDLE THIRD
HEIGHT OF CENTER OF GRAVITY = 84"
DEGREE OF CURVE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
0 1 2 3 4 5 6 7 8 ELEVATION OF OUTER RAIL IN INCHES
VELOCITY IN MILES PER HOUR
0 10 20 30 40 50 60 70 80 90 100 110



SPEEDS OF TRAINS ON CURVES
UNBALANCED ELEVATION = 3"
ALL HEIGHTS OF CENTER OF GRAVITY
THOSE SPEEDS OF TRAINS ON CURVES HAVING AN ELEVATION
OF THREE INCHES LESS THAN THE THEORETICAL ELEVATION

NOTE:–
Unbalanced Speeds for 0" to 8" Elevation are Equivalent to Balanced Speeds for 3" to 11" Elevation.



SPEEDS OF TRAINS THROUGH LEVEL TURNOUTS

RESULTANT OF FORCES THROUGH POINTS AT VARYING DISTANCES FROM CENTER LINE OF TRACK

HEIGHT OF CENTER OF GRAVITY = 84"

NOTE:-

The diagram indicates the respective speeds through the lead curves of the turnouts.

The motion through a straight switch-point being angular, there can be no direct comparison of speed through the switch-point with that through the lead curve. In order to give a rough basis of comparison between the various switch-points and the various lead curves, the speeds through the switch-points are figured for curves whose central angle equals the switch-angle and the length of whose chord equals the length of switch-point. On the above basis, with a wheel-base or truck-center-distance equal to or longer than the switch-point, the rate of turning would equal that through the lead curve.

INDEX TO TRACKWORK PLANS

(For Plans, see "Portfolio of Trackwork Plans")

LAN o.	PLAN Date	TITLE	DATE OF ACCEPTANCE By A. R. E. A.
		Switches	
		Split Switches, Layouts	
1	Sept. 15, 1919	16′ 6″ Split Switch with Uniform Risers	Adopted Mar., 1920
2	Sept. 15, 1919	16′ 6″ Split Switch with Graduated Risers	Adopted Mar., 1920
3	Sept. 15, 1919	11′ 0″ Split Switch with Uniform Risers	Adopted Mar., 1920
4	Sept. 15, 1919	11′ 0″ Split Switch with Graduated Risers	Adopted Mar., 1920
5	Sept. 15, 1919	22′ 0″ Split Switch with Uniform Risers	Adopted Mar., 1920
6	Sept. 15, 1919	22′ 0″ Split Switch with Graduated Risers	Adopted Mar., 1920
7	Sept. 15, 1919	30′ 0″ Split Switch with Uniform Risers	Adopted Mar., 1920
8	Sept. 15, 1919	30′ 0″ Split Switch with Graduated Risers	Adopted Mar., 1920
		Diagrams of Preferred Names of Parts	
90	Sept. 15, 1919	Diagram illustrating Preferred Names of Parts for Split Switches with Uniform Risers	Adopted Mar., 1921
91	Sept. 15, 1919	Diagram illustrating Preferred Names of Parts for Split Switches with Graduated Risers	Adopted Mar., 1921
		Split Switch Fixtures	
1	Sept. 15, 1919	Details of Split Switch Fixtures (General)	Adopted Mar., 1920
2	Sept. 15, 1919	Details of Split Switch Fixtures (Special Features)	Adopted Mar., 1920
3	Sept. 15, 1919	Details of Split Switch Fixtures (Heel Plates and Turnout Plates)	Adopted Mar., 1920
4	Sept. 15, 1919	Details of Split Switch Fixtures (Heel Plates and Turnout Plates for 22′ 0″ and 30′ 0″ Switches)	Adopted Mar., 1920
5	Nov., 1923	Details of Split Fixtures for Rails 6½″ High and Over (General)	Adopted Mar., 1924
6	Nov., 1923	Details of Split Fixtures for Rails 6½″ High and Over (Special Features)	Adopted Mar., 1924
7	Nov., 1923	Details of Split Switch Fixtures for Rails 6½″ High and Over (Heel Plates and Turnout Plates for 11′ 0″ and 16′ 6″ Switches)	Adopted Mar., 1924
8	Nov., 1923	Details of Split Switch Fixtures for Rails 6½″ High and Over (Heel Plates and Turnout Plates for 22′ 0″ and 30′ 0″ Switches)	Adopted Mar., 1924
		Illustration Bills of Material	
10	Sept. 15, 1919	Illustration Bills of Material for 11′ 0″ and 16′ 6″ Split Switches	Adopted Mar., 1920
11	Sept. 15, 1919	Illustration Bills of Material for 22′ 0″ and 30′ 0″ Split Switches	Adopted Mar., 1920
12	Nov., 1923	Illustration Bills of Material for Rails 6½″ High and Over for 11′ 0″ and 16′ 6″ Split Switches	Adopted Mar., 1924
		Derail Switch Point	
13	Nov., 1925	Details for Split Switch Point Derail	Adopted Mar., 1926
		Rail Braces	
10	Nov., 1928	Specifications for Adjustable Rail Braces	Adopted Mar., 1929
		Switch Stands	
51	Nov. 17, 1920	Switch Stand Connecting Rods *and* Requisites for Switch Stands, including Connecting Rods	Adopted Mar., 1921
52	Nov., 1921	Detail of Lamp Tips for Switch Stands	Adopted Mar., 1922
53	Nov., 1922	Detail of Switch Stand Target Shapes	Adopted Mar., 1923
54	Nov., 1921	Day Target Discs for Switch Lamps	Adopted Mar., 1922
55	Nov., 1922	Switch Lock	Adopted Mar., 1923
		Frogs	
		Heavy Rail	
71	Nov., 1928	No. 4 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, and Solid Manganese Steel	*Inform. Mar., 1929
72	Nov., 1928	No. 5 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, and Solid Manganese Steel	*Inform. Mar., 1929
73	Nov., 1928	No. 6 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, Spring Rail, and Solid Manganese Steel	Adopted Mar., 1929
74	Nov., 1928	No. 7 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, Spring Rail, and Solid Manganese Steel	Adopted Mar., 1929
75	Nov., 1928	No. 8 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, Spring Rail, and Solid Manganese Steel	Adopted Mar., 1929
76	Nov., 1928	No. 9 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, Spring Rail, and Solid Manganese Steel	Adopted Mar., 1929
77	Nov., 1928	No. 10 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, Spring Rail, and Solid Manganese Steel	Adopted Mar., 1929
78	Nov., 1928	No. 11 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, Spring Rail, and Solid Manganese Steel	Adopted Mar., 1929
79	Nov., 1928	No. 12 Frogs for Heavy Rails, Rail-Bound Manganese Steel, Bolted Rigid, Spring Rail, and Solid Manganese Steel	Adopted Mar., 1929

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*Accepted as information only.

PLAN No.	PLAN Date	TITLE	DATE OF ACCEPTANC By A. R. E. A.
		Bolted Rigid Frogs	
301	Sept. 15, 1919	No. 6 Bolted Rigid Frog	Adopted Mar., 19
302	Sept. 15, 1919	No. 7 Bolted Rigid Frog	Adopted Mar., 19
303	Sept. 15, 1919	No. 8 Bolted Rigid Frog	Adopted Mar., 19
304	Sept. 15, 1919	No. 10 Bolted Rigid Frog	Adopted Mar., 19
305	Sept. 15, 1919	Detail of Plates for No. 6, 7, 8 and 10 Bolted Rigid Frogs	Adopted Mar., 19
306	Sept. 15, 1919	No. 11 Bolted Rigid Frog	Adopted Mar., 19
307	Sept. 15, 1919	No. 16 Bolted Rigid Frog	Adopted Mar., 19
308	Sept. 15, 1919	Detail of Plates for No. 11, 16 and 20 Bolted Rigid Frogs	Adopted Mar., 19
309	Oct. 19, 1920	No. 4 and No. 5 Bolted Rigid Frogs	*Inform. Mar., 19
320	Nov., 1920	Data for Laying Out Bolted Rigid Frogs	Adopted Mar., 19
321	Nov., 1925	Tie Layout Standard Length Rigid Frogs for One-piece Guard Rail, 6 Ties, 19″ to 20″ Spacing, Suspended Joints	*Inform. Mar., 192
325	Nov., 1925	Frog Fillers for Rails 80 lb. per Yard and Heavier	*Inform. Mar., 192
		Clamp Frogs	
331	Sept. 15, 1919	No. 6 Clamp Frog	Adopted Mar., 192
332	Sept. 15, 1919	No. 7 Clamp Frog	Adopted Mar., 192
333	Sept. 15, 1919	No. 8 Clamp Frog	Adopted Mar., 192
334	Sept. 15, 1919	No. 10 Clamp Frog	Adopted Mar., 192
335	Sept. 15, 1919	Detail of Plates for No. 6, 7, 8 and 10 Clamp Frogs	Adopted Mar., 192
		Bolted Rigid Self-Guarded Frogs	
341	Nov., 1928	No. 6 Bolted Rigid Self-Guarded Frog	Adopted Mar., 192
342	Nov., 1928	No. 7 Bolted Rigid Self-Guarded Frog	Adopted Mar., 192
*343	Nov., 1927	No. 8 Rigid Bolted Self-Guarded Frog	Adopted Mar., 192
344	Nov., 1928	No. 10 Bolted Rigid Self-Guarded Frog	Adopted Mar., 192
		Diagrams of Preferred Names of Parts	
390	Sept. 15, 1919	Diagram illustrating Preferred Names of Parts for Bolted Rigid Frogs	Adopted Mar., 192
391	Sept. 15, 1919	Diagram illustrating Preferred Names of Parts for Clamp Frogs	Adopted Mar., 192
		Spring Rail Frogs	
401	Sept. 15, 1919	No. 10 Spring Rail Frog	Adopted Mar., 192
402	Sept. 15, 1919	No. 8 Spring Rail Frog	Adopted Mar., 192
403	Sept. 15, 1919	No. 11 Spring Rail Frog	Adopted Mar., 192
404	Nov., 1923	No. 10 Spring Rail Frog for Rails 6½″ High and Over	Adopted Mar., 192
420	Nov., 1922	Data for Laying Out Spring Rail Frogs	Adopted Mar., 192
490	Sept. 15, 1919	Diagram illustrating Preferred Names of Parts for Spring Rail Frogs	Adopted Mar., 192

Guard Rails

501	Nov., 1920	Details of Guard Rails	Adopted Mar., 192
502	Nov., 1920	Details of Guard Rail Fixtures	Adopted Mar., 19
510	Nov., 1928	Manganese Steel One-piece Guard Rail on 6 Ties	*Inform. Mar., 192
590	Sept. 15, 1919	Diagram illustrating Preferred Names of Parts for Guard Rails	Adopted Mar., 19

Frogs, Manganese

		Rail Bound Manganese Steel Frogs	
†600	Nov., 1927	Data for Laying Out Rail Bound Manganese Steel Frogs	Adopted Mar., 192
602	Sept. 15, 1919	No. 7 Rail Bound Manganese Steel Frog	Adopted Mar., 192
603	Sept. 15, 1919	No. 8 Rail Bound Manganese Steel Frog	Adopted Mar., 192
604	Sept. 15, 1919	No. 10 Rail Bound Manganese Steel Frog	Adopted Mar., 192
605	Sept. 15, 1920	No. 11 Rail Bound Manganese Steel Frog	Adopted Mar., 192
606	Sept. 15, 1919	No. 16 Rail Bound Manganese Steel Frog	Adopted Mar., 192
607	Sept. 15, 1919	No. 20 Rail Bound Manganese Steel Frog	Adopted Mar., 192
608	Oct. 19, 1920	No. 4 and No. 5 Rail Bound Manganese Steel Frogs	*Inform. Mar., 192
609	Nov., 1927	Nos. 9, 12 and 14 Rail Bound Manganese Steel Frogs	Adopted Mar., 192
610	Nov., 1927	Nos. 15 and 18 Rail Bound Manganese Steel Frogs	Adopted Mar., 192
		Solid Manganese Steel Self-Guarded Frogs	
640	Nov., 1928	Standard Dimensions for Solid Manganese Steel Self-Guarded Frogs	Adopted Mar., 192
643	Nov., 1928	No. 8 Self-Guarded Frog, Solid Manganese Steel	Adopted Mar., 192

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*Accepted as information only.

†Plan adopted March, 1928; Rules adopted March, 1921.

AN	PLAN Date	TITLE	DATE OF ACCEPTANCE By A. R. E. A.
		Solid Manganese Steel Frogs	
1	Sept. 15, 1919	No. 6 Solid Manganese Steel Frog	Adopted Mar., 1920
2	Sept. 15, 1919	No. 7 Solid Manganese Steel Frog	Adopted Mar., 1920
3	Sept. 15, 1919	No. 8 Solid Manganese Steel Frog	Adopted Mar., 1920
4	Sept. 15, 1919	No. 10 Solid Manganese Steel Frog	Adopted Mar., 1920
5	Sept. 15, 1919	No. 11 Solid Manganese Steel Frog	Adopted Mar., 1920
6	Oct. 19, 1920	No. 4 and No. 5 Solid Manganese Steel Frogs	*Inform. Mar., 1921
0	Nov., 1928	Standard Dimensions for Solid Manganese Steel Frogs	Adopted Mar., 1929
		Diagrams of Preferred Names of Parts	
0	Sept. 15, 1919	Diagram illustrating Preferred Names of Parts for Rail Bound Manganese Steel Frogs	Adopted Mar., 1921
1	Sept. 15, 1919	Diagram illustrating Preferred Names of Parts for Solid Manganese Steel Frogs	Adopted Mar., 1921
		Crossings	
0	Nov., 1926	Application of Crossing Designs and Recommended Practices	Adopted Mar., 1927
0-A		Data and Record Sheet for Ordering Crossings	Adopted Mar., 1923
0-A	Example No. 1	Data and Record Sheet for Ordering Crossings	Adopted Mar., 1923
0-A	Example No. 2	Data and Record Sheet for Ordering Crossings	Adopted Mar., 1923
0-B	Nov., 1924	Data and Record Sheet for Ordering Compromise Joints	Adopted Mar., 1925
0-C	Nov., 1924	Data and Record Sheet for Ordering Compromise Rails	Adopted Mar., 1925
		Bolted Rail Crossings	
1	Oct., 1921	Three Rail Design—Angles 90° to 50°, inclusive	Adopted Mar., 1922
2	Oct., 1921	Two Rail Design—Angles 90° to 50°, inclusive	Adopted Mar., 1922
3	Oct., 1921	Three Rail Design—Angles below 50° to 35°, inclusive	Adopted Mar., 1922
4	Oct., 1921	Two Rail Design—Angles below 50° to 35°, inclusive	Adopted Mar., 1922
5	Oct., 1921	Three Rail Design—Angles below 35° to 25°, inclusive	Adopted Mar., 1922
6	Oct., 1921	Two Rail Design—Angles below 35° to 25°, inclusive	Adopted Mar., 1922
7	Oct., 1921	Single Rail Design and Two Rail Design with Short Easer Rails—Angles below 25° and above 14° 15′	Adopted Mar., 1922
8	Oct., 1921	Single Rail Design and Two Rail Design—Angles below 25° and above 14° 15′	Adopted Mar., 1922
9	Oct., 1921	Single Rail Design and Two Rail Design with Short Easer Rails—Angles 14° 15′ to 8° 10′, inclusive	Adopted Mar., 1922
10	Oct., 1921	Single Rail Design and Two Rail Design—Angles 14° 15′ to 8° 10′, inclusive	Adopted Mar., 1922
		Bolted Rail Crossings, Electric Railway over Steam Railroad	
16	Nov., 1924	Bolted Rail Crossings, Steam Railroad over Electric Railway—Angles 90° to 50°, inclusive	Adopted Mar., 1925
17	Nov., 1924	Bolted Rail Crossings, Steam Railroad over Electric Railway—Angles below 50° to 30°, inclusive	Adopted Mar., 1925
		Tie Layouts for Railroad Crossings	
19-A	Nov., 1928	Tie Layout for Railroad Crossings, angles 8° 10′ to 14° 15′	Adopted Mar., 1929
19-B	Nov., 1928	Tie Layout for Railroad Crossings, angles 14° 15′ to 25°	Adopted Mar., 1929
19-C	Nov., 1928	Tie Layout for Railroad Crossings, angles 25° to 50°	Adopted Mar., 1929
19-D	Nov., 1928	Tie Layout for Railroad Crossings, angles 50° to 90°	Adopted Mar., 1929
		Reinforced Concrete and Pile Crossing Foundations	
21	Nov., 1927	Design of Reinforced Concrete and Pile Crossing Foundations	Adopted Mar., 1928
		Manganese Steel Insert Crossings	
51	Nov., 1920	Designs and Dimensions of Inserts, Detail A—Angles 45° to above 14° 15′	Adopted Mar., 1922
52	Nov., 1920	Designs and Dimensions of Inserts, Detail B—Angles 45° to above 14° 15′	Adopted Mar., 1922
53	Nov., 1920	Designs and Dimensions of Inserts—Angles 14° 15′ to 8° 10′, inclusive	Adopted Mar., 1922
54	Oct., 1921	Three Rail Design, Detail A—Angles below 45° to 35°, inclusive	Adopted Mar., 1922
55	Oct., 1921	Two Rail Design, Detail A—Angles below 45° to 35°, inclusive	Adopted Mar., 1922
56	Oct., 1921	Three Rail Design, Detail A—Angles below 35° to 25°, inclusive	Adopted Mar., 1922
57	Oct., 1921	Two Rail design, Detail A—Angles below 35° to 25°, inclusive	Adopted Mar., 1922
58	Oct., 1921	Two Rail Design with Short Easer Rails, Detail A—Angles below 25° and above 14° 15′	Adopted Mar., 1922
59	Oct., 1921	Two Rail Design, Detail A—Angles below 25° and above 14° 15′	Adopted Mar., 1922

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*Accepted as information only.

PLAN No.	PLAN Date	TITLE	DATE OF ACCEPTANC By A. R. E. A.
760	Oct., 1921	Single Rail Design with Short Easer Rails, Detail A—Angles below 25° and above 14° 15′	Adopted Mar., 192
761	Oct., 1921	Single Rail Design, Detail A—Angles below 25° and above 14° 15′	Adopted Mar., 192
762	Oct., 1921	Three Rail Design, Detail B—Angles below 45° to 35°, inclusive	Adopted Mar., 192
763	Oct., 1921	Three Rail Design, Detail B—Angles below 35° to 25°, inclusive	Adopted Mar., 192
764	Oct., 1921	Two Rail Design with Short Easer Rails, Detail B—Angles below 35° to 25°, inclusive	Adopted Mar., 192
765	Oct., 1921	Two Rail Design with Short Easier Rails, Detail B—Angles below 25° and above 14° 15′	Adopted Mar., 192
766	Oct., 1921	Single Rail Design with Short Easer Rails, Detail B—Angles below 25° and above 14° 15′	Adopted Mar., 192
767	Oct., 1921	Two Rail Design—Angles 14° 15′ to 8° 10′, inclusive	Adopted Mar., 192
768	Oct., 1921	Single Rail Design—Angles 14° 15′ to 8° 10′, inclusive	Adopted Mar., 192
		Manganese Steel Insert Crossings, Electric Railway over Steam Railroad	
778	Nov., 1925	Manganese Steel Insert Crossings, Steam Railroad over Electric Railway, Angles below 45° to 30° inclusive	Adopted Mar., 192
		Insulated Internal Joints	
770	Nov., 1922	Insulated Internal Joint for Crossings, Three Rail Design—Angles, below 45° to 25°, inclusive	*Inform. Mar., 192
		Solid Manganese Crossings	
771	Nov., 1923	Solid Manganese Steel Crossings—Angles 90° to 60°, inclusive	Adopted Mar., 1924
771-B	Nov., 1924	Solid Manganese Steel Crossings—Angles 90° to 60°, inclusive, Design No. 2 and Design No. 3, Alternates for Design detailed on Plan 771	*Inform. Mar., 1925
772	Nov., 1923	Solid Manganese Steel Crossings—Angles below 60° to 40°, inclusive	Adopted Mar., 1924
773	Nov., 1924	Solid Manganese Steel Crossings—Angles below 40° to 25°, inclusive	Adopted Mar., 1925
774	Nov., 1926	Solid Manganese Steel Crossings with Interior Connecting Rails, Double Rail Construction—Angles below 25° and above 14° 15′	Adopted Mar., 1927
775	Nov., 1927	Solid Manganese Steel Crossings, with Interior Connecting Rails, Single Rail Construction, angles, 14° 15′ to 8° 10′, inclusive	Adopted Mar., 1928
		Solid Manganese Crossings, Electric Railway over Steam Railroad	
776	Nov., 1923	Solid Manganese Steel Crossings, Steam Railroad over Electric Railway—Angles 90° to 60°, inclusive	Adopted Mar., 1924
777	Nov., 1923	Solid Manganese Steel Crossings, Steam Railroad over Electric Railway—Angles below 60° to 40°, inclusive	Adopted Mar., 1924
780	Nov., 1926	Solid Manganese Steel Crossings, Steam Railroad over Electric railway, for 7″ and 9″ girder rails, angles 90° to 60°, inclusive	Adopted Mar., 1927
781	Nov., 1926	Solid Manganese Steel Crossings, steam railroad over electric railway, for 7″ and 9″ girder rails, angles below 60° to 40°, incl.	Adopted Mar., 1927
		Tables for Gages and Flangeways	
791	Nov., 1921	*Table No. 1*—Gages and Flangeways in Curved Track	Adopted Mar., 1922
792	Nov., 1921	*Table No. 2*—Gages and Flangeways in Curved Track—Gage Diagrams for Rigid Wheel Base Locomotives	Adopted Mar., 1922

Double Slip Switches

		Double Slip Switch Layouts	
801	Nov., 1922	No. 8 Double Slip Switch with Movable Center Points with Uniform Risers	Adopted Mar., 1923
802	Nov., 1922	No. 8 Double Slip Switch with Movable Center Points with Graduated Risers	Adopted Mar., 1923
803	Nov., 1923	No. 10 Double Slip Switch with Movable Center Points with Uniform Risers	Adopted Mar., 1924
804	Aug., 1923	No. 10 Double Slip Switch with Movable Center Points with Graduated Risers	Adopted Mar., 1924
		Details of Double Slip Switches	
851	Nov., 1922	Details of No. 8 Double Slip Switch with Movable Center Points with Uniform Risers	Adopted Mar., 1923
852	Nov., 1922	Details of No. 8 Double Slip Switch with Movable Center Points with Graduated Risers	Adopted Mar., 1923
853	Nov., 1923	Details of No. 10 Double Slip Switch with Movable Center Points with Uniform Risers	Adopted Mar., 1924
854	Aug., 1923	Details of No. 10 Double Slip Switch with Movable Center Points with Graduated Risers	Adopted Mar., 1924

PLAN No.	PLAN Date	TITLE	DATE OF ACCEPTANCE By A. R. E. A.
		Diagram of Preferred Names of Parts	
890	Nov., 1924	Diagram illustrating Preferred Names of Parts of Double Slip Switch with Movable Center Points	Adopted Mar., 1925
		Turnouts and Crossovers	
900	Nov., 1920	Table of Practical Turnout Leads *and* Table of Theoretical Turnout Leads	Adopted Mar., 1921
		Turnout and Crossover Layouts	
901	Sept. 20, 1920	Layout of No. 6 Turnout and Crossover	Adopted Mar., 1921
902	Sept. 20, 1920	Layout of No. 7 Turnout and Crossover	Adopted Mar., 1921
903	Sept. 20, 1920	Layout of No. 8 Turnout and Crossover with Rigid Frogs	Adopted Mar., 1921
904	Sept. 20, 1920	Layout of No. 8 Turnout and Crossover with Spring Frogs	Adopted Mar., 1921
905	Sept. 20, 1920	Layout of No. 10 Turnout and Crossover	Adopted Mar., 1921
906	Sept. 20, 1920	Layout of No. 11 Turnout and Crossover	Adopted Mar., 1921
907	Sept. 20, 1920	Layout of No. 16 Turnout and Crossover	Adopted Mar., 1921
908	Sept. 20, 1920	Layout of No. 20 Turnout and Crossover	Adopted Mar., 1921
		Movable Point Crossings	
951	Nov., 1926	Layout of No. 7 Movable Point Crossing	Adopted Mar., 1927
952	Nov., 1926	Details of Manganese Knuckle Rails and Details of Plates for No. 7 Movable Point Crossing	Adopted Mar., 1927
953	Nov., 1927	Graph and Details of Movable Points for Curved Crossings, angles 8° 10′ to 15° 30′, inclusive	Adopted Mar., 1928
954	Nov., 1926	Details of Manganese Rail Bound Knuckle Rails for No. 8 and No. 10 Slip Switches	Adopted Mar., 1927
955	Nov., 1927	Details of Solid Manganese Steel Knuckle Rail for No. 8 and No. 10 Slip Switches	Adopted Mar., 1928
		Track Construction for Paved Streets	
980	Nov., 1926	Alinement details for turnouts, tongue switch construction, for use in paved streets	Adopted Mar., 1927
983	Nov., 1927	Solid Manganese Steel Frogs for 7″ and 9″ Girder Rails	Adopted Mar., 1928
984	Nov., 1927	Nos. 4 and 5 Frogs, Iron Bound Manganese Steel Center, for 7″ and 9″ Girder Rails	Adopted Mar., 1928
985	Nov., 1927	Nos. 6 and 8 Frogs, Iron Bound Manganese Steel Center, for 7″ and 9″ Girder Rails	Adopted Mar., 1928
986	Nov., 1927	No. 10 Frog, Iron Bound Manganese Steel Center, for 7″ and 9″ Girder Rails	Adopted Mar., 1928
		Specifications and Definitions	
Appendix A		Specifications for the Design and Dimensions of Manganese Steel Pointed Switches	Adopted Mar., 1920
Appendix B		Specifications for Switches, Frogs, Crossings and Guard Rails	Adopted Mar., 1921
Appendix C		Definitions of Switch, Frog, Guard Rail, Crossing and Turnout Terms	Adopted Mar., 1924

SPECIFICATIONS FOR SWITCHES, FROGS, CROSSINGS AND GUARD RAILS

(See Appendix B, pages 1 and 2, in "Portfolio of Trackwork Plans.")

PLANS AND SPECIFICATIONS FOR SWITCH STANDS, SWITCH LAMPS AND SWITCH LOCKS

(See Plans 254 and 255, in "Portfolio of Trackwork Plans.")

FROG DESIGNS (Bolted Rigid and Rail Bound Manganese Steel)

(See Plans 320 and 600 in "Portfolio of Trackwork Plans.")

SOLID MANGANESE STEEL FROGS

(See Plans 651 to 656, inclusive, and Plan 670 in "Portfolio of Trackwork Plans.")

SPECIFICATIONS FOR THE DESIGN AND DIMENSIONS OF MANGANESE STEEL POINTED SWITCHES

(See Appendix A in "Portfolio of Trackwork Plans.")

[7]SPECIFICATIONS FOR FROG FILLER SECTIONS

(I) MANUFACTURE

Process

1. The steel shall be made by either or both the following processes: Bessemer or Open-Hearth.

2. Bars shall be hot rolled.

(II) CHEMICAL PROPERTIES

3. Steel shall conform to A.S.T.M. specifications for commercial bar steel, in so far as they apply to this product, serial designation A-80-24, of the following grades.

	Open-Hearth	*Bessemer*
Carbon	.15 to .30	.12 to 25

(III) PERMISSIBLE VARIATIONS IN DIMENSIONS

4. The fishing height of filler shall not exceed that shown in drawings by more than 1/64 inch and shall not underrun by more than 1/32 inch.

Width of filler between rail webs shall be nothing under to 1/16 inch over dimensions shown.

Depth of flangeway groove may be 1/16 inch under or 1/8 inch over dimensions given on drawing.

(IV) GROUPING

In order to reduce the large number of sections now rolled, fillers recommended as standard have been grouped as shown on Plan 325.

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[7] Adopted, Vol. 27, 1926, pp. 642, 1369.

SPECIFICATIONS FOR RELAYER RAIL FOR VARIOUS USES[8]

Definition

1. Worn rails suitable for use in track are known as relayer rails.

Classification

2. Relayer rails shall be classified according to the wear on the side and top of the head:

(a) Side wear shall be represented by figures 0, representing no side wear, 1, 2, 3, etc., representing the number of sixteenths of an inch wear on the side of the head at the gage 5/8 inch below the original top of the rail.

(b) Top wear shall be represented by capital letters, O representing no top wear, A representing 1/32 inch, B, 2/32 inch, C, 3/32 inch, etc., wear, measured at the center of the rail.

(c) If the rail head is worn on both sides the first figure shall represent the side showing the greater wear, the letter the top wear, and the figure following the lesser side wear.

(d) The maximum wear allowed in each case shall be specified by the user or the purchaser.

Process and Section

3. The process, as Bessemer, Open-Hearth, special alloy or process steel, the section, the original weight per yard and the splice drilling shall be specified.

Main Track Relayer Rails

4. *Grade 1.*—Used rails suitable for main track on main or branch lines. They must be free from all physical defects and shall pass the A.R.E.A. Specifications for Carbon Steel Rail in all respects except wear. The surface of the rails of this grade must be fairly smooth and shall not have flat spots or wheel burns. They shall be sawed at the ends, not cut with a chisel. Drilling shall be uniform. Chemical analysis or the specifications under which the rails were originally purchased shall be furnished when requested by the purchaser. There shall be full length pieces, 30, 33 or 39 feet long, and not over 10 per cent of shorts varying in lengths by one foot with a minimum length of 22 feet.

Resawing Rails

5. *Grade, 2.*—All rails with battered or otherwise defective ends, which if resawed would meet the Grade 1 requirements, shall be graded as Resawed Main Track Relayer Rails. In this case 90 per cent of the rails shall be of uniform length, 27 feet or over.

Side Track Relayer Rails

6. *Grade 3.*—All used rails suitable for side tracks shall be included in this grade. They shall be not less than 15 feet long. Rails too badly out of line or surface to be included in Grade 1 but straight enough to be easily spiked to line and gage shall be accepted. Drilling shall be uniform. Base shall be full or uniform width.

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[8] Adopted, Vol. 21, 1920, pp. 192, 1374.

Any physical defects, such as broken lower flange, corroded, curved ends, burnt, ends battered, ends down, flat spots, head flow, line bent, piped, pitted, short, split end, split head, surface bent, twisted, worn under head, shall be specified where they occur and the extent of the defect shall be represented by the use of the term "slight," "moderate" or "bad."

Scrap Rails (Rolling Mill Rails)

7. *Grade 4.*—Rails of standard section not suitable for use as relayer rails. They shall be not less than 6 feet long and shall be free from pipes, split heads and similar defects. Badly twisted rails or bent rails, frogs, switches and guard rails will not be accepted.

Scrap Rails

8. *Grade 5.*—All used rails of any length or condition not meeting the above specifications shall be designated as Grade 5.

Marking and Shipping

9. Rails when classified shall be marked with white paint on the web about 3 feet from the end. The figure and letter representing the side and top wear shall be painted first, followed by a dash (—) and the grade number, except scrap rails, shall be marked by the grade number only. No two grades of rails shall be loaded in the same car.

Examples

10. (a) Main track relayer rails having 3/16 inch side wear and 3/32 inch top wear would be classified and marked 3 C—1.

(b) Resawed main track relayer rails having ¼ inch side wear and 5/32 inch top wear would be classified and marked 4 C—2.

(c) Side track relayer rails having ½ inch side wear and ⅛ inch top wear would be classified and marked 8 D—. If there are any physical defects, as curved ends, line bent, pitted, etc., they should be so classified and the extent of the defects specified as "slight," "moderate" or "bad."

(d) Side track relayer rails having ½ inch side wear on one side and ⅜ inch side wear on the other side, ⅛ inch top wear, would be classified and marked 8 D 6—3. If there are any physical defects, as curved ends, line bent, pitted, etc., they should be so classified and the extent of the defect specified as "slight," "moderate" or "bad."

[9]RESAWING AND RECONDITIONING OF RAILS FOR RELAYING, AND BUILDING UP OF BATTERED RAIL ENDS IN TRACK

(1) There is no economy in rerolling rail at present high costs. With the necessity for renewing rail of 100-lb. or greater section, the practice of rerolling rail will probably increase on account of the fact that the rerolled section will provide a relatively satisfactory section after rerolling.

As the quality of rail to be rerolled increases the price of rerolling will be rapidly reduced.

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[9] Adopted, Vol. 26, 1925, pp. 568, 1404.

(2) The resawing of rail for relayers is economical and is good practice. It is desirable, when conditions warrant, to do this work with a portable rail saw.

(3) The reconditioning of joints with the oxy-acetylene process is good practice and is the most economical method, all things considered, of reconditioning rail for renewal in the track.

[10]TEMPERATURE EXPANSION FOR LAYING RAILS

(1) When laying rails their temperature should be taken by applying a thermometer. To allow for expansion, openings between the ends of rail should be as follows:

Temperature of Rail—Degree Fahr.	160 Jts. Per Mile 33′0″ Rails	135 Jts. Per Mile 39′0″ Rails	117 Jts. Per Mile 45′0″ Rails
—20° to 0°	5/16″	3/8″	7/16″
0° to 25°	1/4″	9/32″	11/32″
25° to 50°	3/16″	7/32″	1/4″
50° to 75°	1/8″	1/8″	5/32″
75° to 100°	1/16″	1/16″	1/16″
Over 100°	Laid Close	Laid Close	Laid Close

[11]CANTING OF RAIL INWARD

(1) Rail should be canted inwardly.
(2) Inclined tie plates should be used to produce the desired result.

[12]STANDARD RAIL JOINT

A standard rail joint should fulfill the following general requirements:

(1) It should connect the rails into a uniform continuous girder.

(2) It should be strong enough to resist deformation or taking permanent set.

(3) It should prevent relative deflection or vertical movement of the ends of the rails and permit movement lengthwise for expansion.

(4) It should be as simple and of as few parts as possible to be effective.

[13]DESIGN OF TRACK FASTENINGS

(1) Where there is material leakage from track circuits, track fastenings should be so designed as to prevent contact between the metal and the ballast.

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[10] Revision in preparation.

[11] Adopted, Vol. 27, 1926, pp. 655, 1373.

[12] Adopted, Vol. 7, 1906, pp. 655, 657; Vol. 16, 1915, pp. 729, 1145.

[13] Adopted, Vol. 11, Part 2, 1910, pp. 935, 942, 944.

[14]SPECIFICATIONS FOR STEEL TIE PLATES

1. These specifications cover two grades of steel tie plates, namely: soft and medium. The soft grade will be used unless otherwise specified.

(I) MANUFACTURE

2. Steel may be made by the Bessemer or Open-Hearth process, or both.

(II) CHEMICAL PROPERTIES AND TESTS

3. (a) The steel shall conform to the following requirements as to chemical composition:

(b) Phosphorus

Bessemer—not over 0.10 per cent.
Open-Hearth—not over 0.05 per cent.

(c) Carbon

Unless otherwise specified, the material will be furnished according to chemical composition only, in which case the minimum carbon shall be as follows:

Bessemer—soft grade—not under 0.08 per cent.
Bessemer—medium grade—not under 0.12 per cent.
Open-Hearth—soft grade—not under 0.15 per cent.
Open-Hearth—medium grade—not under 0.20 per cent.

4. A carbon determination shall be made of each melt of Bessemer steel, and three analyses every 24 hours representing the average of the elements carbon and phosphorus contained in the steel, one for each 8-hour turn, respectively. These analyses shall be made from drillings taken at least ⅛ inch beneath the surface of a test ingot obtained during the pouring of the melts. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

5. An analysis of each melt of open-hearth steel shall be made by the manufacturer to determine the percentages of carbon and phosphorus. This analysis shall be made from drillings taken at least ⅛ inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

6. An analysis may be made by the purchaser from a finished tie plate representing each melt of open-hearth steel, and each melt or lot of 10 tons of Bessemer steel. The carbon content thus determined shall not be less than that specified in Section 3, and the phosphorus content shall not exceed that specified in Section 3 by more than 25 per cent.

(III) PHYSICAL PROPERTIES AND TESTS

7. The bend test specimens specified in Section 8 shall bend cold through 180 deg. around a pin the diameter of which is equal to the thickness of the specimen for the soft grade, and to twice the thickness of the

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[14] Adopted, Vol. 27, 1926, pp. 633, 1367.

specimen for the medium grade, without cracking on the outside of the bent portion.

8. Bend test specimens shall be taken from the finished tie plates, or from the rolled bars, and longitudinally with the rolling. They shall be rectangular in section, not less than ½ inch in width between the planed sides, and shall have two faces as rolled. They shall be free from ribs or projections. Where the design of the tie plates is such that the specimen cannot be taken between the ribs or projections, those ribs or projections shall, in preparing the specimen, be planed off even with the main surface of the tie plate.

9. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 7:

> A piece of the rolled bar shall bend cold through 90 degrees around a pin the diameter of which is equal to the thickness of the section where bent for the soft grade, and to twice the thickness of the section where bent for the medium grade, without cracking on the outside of the bent portion.

10. (a) One bend test shall be made from each melt of open-hearth steel, or from each melt or lot of 10 tons of Bessemer steel.

(b) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(IV) WORKMANSHIP AND FINISH

11. (a) The tie plate shall conform to the dimensions specified by the purchaser with the following permissible variations.

(b) For plates with shoulders parallel to the direction of rolling, a variation of 1/32 inch in thickness, ⅛ inch in rolled width, and 3/16 inch in sheared length will be permitted.

(c) For plates with shoulders perpendicular to the direction of rolling, a variation of 1/32 inch in thickness, 3/16 inch in rolled width, and ¼ inch in sheared length will be permitted. The distance from the face of shoulder to the outside end of the plate shall not vary more than ⅛ inch and from the face of shoulder to the inside end not more than ¼ inch.

(d) A variation of not more than 1/32 inch in the length of their sides and in the location of spike holes will be permitted.

12. The tie plate shall be smoothly rolled, true to templet, and shall be straight and out of wind on the surface which will form the bearings for the rail.

13. The finished tie plates shall be free from burrs and other surface deformation caused by the shearing and punching; they shall also be free from other injurious defects and shall have a workmanlike finish.

(V) MARKING

14. The name or brand of the manufacturer, the section and the year of manufacture shall be rolled in raised letters and figures on the outside of the shoulder of the plates, and a portion of this marking shall appear on each finished tie plate.

(VI) INSPECTION

15. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tie plates ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tie plates are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

16. Unless otherwise specified, any rejections based on tests made in accordance with Section 6 shall be reported within five working days from the receipt of samples.

17. Tie plates which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

18. Samples tested in accordance with Section 6, which represent rejected tie plates, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

[15]SPECIFICATIONS FOR WROUGHT IRON TIE PLATES

(I) MATERIAL

1. Plates shall be made of all-pig puddled iron.

(II) PHYSICAL REQUIREMENTS

2. The material shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	48,000
Yield point, lb. per sq. in.	0.6 tensile strength
Elongation in 2 inches, per cent	28
Elongation in 8 inches, per cent	25
Reduction of area, per cent	37

Bend Tests

3. The bend test specimen shall bend cold through 180 degrees without fracture around a pin, the diameter of which is equal to the thickness of the specimen.

Test Specimens

4. (a) The tension test specimens shall be taken from the finished tie plates, or from the rolled bar. They shall be cut so that the sides of the specimens are parallel to the direction in which the tie plates have been rolled.

(b) Tension test specimens may conform to the essential dimensions shown in Fig. 1 or Fig. 2. The 2-inch specimen (Fig. 1) shall have filleted shoulders, or threaded ends, to fit into the holders on the testing machine in such a way that the line of action of the force exerted by the testing machine shall coincide with the axis of the specimen.

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[15] Adopted, Vol. 21, 1920, pp. 182, 1369.

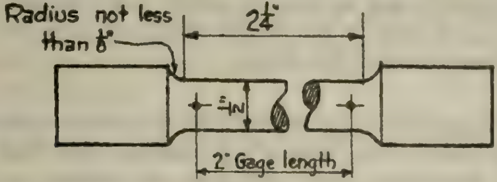

Fig. 1

NOTE.—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.

Number of Tests

5. (a) One tension test and one bend test shall be made from each lot of 1000 tie plates.

(b) If any test specimen from either of the bars originally selected to represent a lot of material contains surface defects not visible before testing, but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

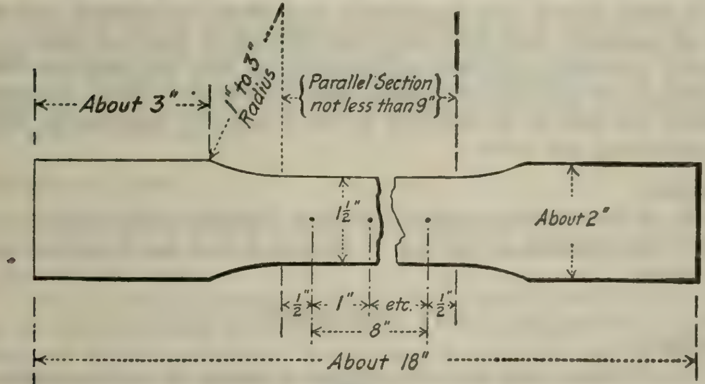

Fig 2

(III) DESIGN

Plan

6. The tie plates shall conform to the drawings submitted to the manufacturer, with the following permissible variations:

Variations

(a) For plates with shoulders parallel to the direction of rolling a variation of 1/32 inch in thickness, ⅛ inch in rolled width, and 3/16 inch in sheared length will be permitted.

(b) For plates with shoulders perpendicular to the direction of rolling, a variation of 1/32 inch in thickness, ⅛ inch in rolled width, and ¼ inch in sheared length will be permitted. The distance from the face of the shoulder to the outside end of plate shall not vary more than ¼ inch, and from the face of shoulder to the inside end not more than ½ inch.

(IV) MANUFACTURE

Workmanship

7. The tie plate shall be smoothly rolled, true to templet, and shall be straight and out of wind on the surface which will form the bearings for the rail and have a workmanlike finish.

Finish

8. The finished tie plates shall be free from burrs and other surface deformations caused by the shearing and punching; they shall also be free from slivers, depressions, seams, crop ends and evidences of being burnt.

Marking

9. The name or brand of the manufacturer, the section and the year of manufacture shall be rolled in raised letters and figures on the outside of the shoulder of the plates, and a portion of this marking shall appear on each finished tie plate.

(V) INSPECTION

Inspection

10. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tie plates ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tie plates are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

11. If either of the test bars selected to represent a lot does not conform to the requirements specified in Sections 2, 3, 4 and 5, the lot will be rejected.

(VI) SHIPMENT

Packing

12. Tie plates shall be wired together in bundles of uniform number, weighing not to exceed 100 lb., for shipment, unless otherwise specified.

[16]SPECIFICATIONS FOR MALLEABLE IRON TIE PLATES

(I) MATERIAL

1. Plates shall be made from furnace malleable iron.

(II) PHYSICAL REQUIREMENTS

Tension Tests

2. The tension test specimens specified in Section 4 shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45,000
Elongation in 2 inches, per cent	7.5

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[16] Adopted, Vol. 21, 1920, pp. 185, 1369.

Special Tests

3. (a) All tie plates shall have cast thereon test lugs of a size proportional to the thickness of the tie plate, but not exceeding 5/8 by 3/4 inch in cross-section. These lugs shall be attached to the tie plate at such a point that they will not interfere with the assembling of the tie plates, and may be broken off by the inspector.

(b) If the purchaser or his representative so desires, a tie plate may be tested to destruction. Such a tie plate shall show good, tough malleable iron.

Tension Test Specimens

4. (a) Tension test specimens shall be of the form and dimensions shown in Fig. 1. Specimens whose mean diameter at the smallest section is less than 19/32 inch will not be accepted for test.

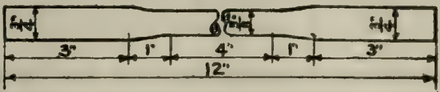


Fig. 1.

(b) A set of three tension test specimens shall be cast from each melt, without chills, using risers of sufficient height to secure sound bars. The specimens shall be suitably marked for identification with the melt. Each set of specimens so cast shall be placed in some one oven containing tie plates to be annealed.

Number of Tests

5. (a) After annealing, three tension test specimens shall be selected by the inspector as representing the tie plates in the oven from which these specimens are taken.

(b) If the first specimen conforms to the specified requirements, or if, in the event of failure of the first specimen, the second and third specimens conform to the requirements, the tie plates in that oven shall be accepted, except that any tie plate may be rejected if its test lug shows that it has not been properly annealed. If either the second or third specimen fails to conform to the requirements, the entire contents of that oven shall be rejected.

Reannealing

6. Any tie plates rejected for insufficient annealing may be reannealed once. The reannealed tie plates shall be inspected and if the remaining test lugs or tie plates broken as specimens show the tie plates to be thoroughly annealed, they shall be accepted; if not, they shall be finally rejected.

(III) DESIGN

Plan

7. Tie plates shall conform to the drawing submitted to the manufacturer, with the following permissible variations:

Variation

(a) The length and width shall not vary more than ⅛ inch from the dimensions shown.

(b) The thickness shall not vary more than $\frac{1}{32}$ inch from the dimensions shown.

(IV) MANUFACTURE

Workmanship

8. The plates shall be straight and out of wind on the surface which forms the bearing for the rail, and shall be made in a workmanlike manner.

Finish

9. The finished tie plate shall be well cleaned and free from warping, shrinkage, cracks, blowholes, fins, and other imperfections.

Marking

10. The manufacturer's identification mark and the pattern numbers assigned by the purchaser shall be cast on all tie plates in such positions that they will not interfere with the service of the tie plate.

(V) INSPECTION

Inspection

11. (a) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tie plates ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tie plates are being furnished in accordance with the specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(b) The manufacturer shall be required to keep a record of each melt from which tie plates are produced, showing tensile strength and elongation of test specimens cast from such melts. These records shall be available and shown to the inspector whenever required.

Rejection

12. Tie plates which show injurious defects subsequent to their acceptance at the manufacturer's works may be rejected, and, if rejected shall be replaced by the manufacturer free of cost to the purchaser.

(VI) SHIPMENT

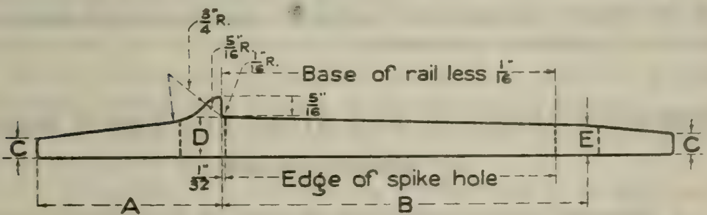
Packing

13. Tie plates shall be wired together in bundles of uniform number, weighing not to exceed 100 lb., for shipment, unless otherwise specified.

[17]TABLE OF DIMENSIONS FOR TIE PLATES

LENGTH OF PLATES	RANGE OF RAIL BASES	SAME FOR FLAT AND CANTED PLATES			FLAT PLATES	CANTED 1 IN 40		CANTED 1 IN 20	
		A	B	C	D & E	D	E	D	E
9″	$4\frac{3}{4}''$ TO 5″	$2\frac{3}{8}''$	$5\frac{3}{8}''$	$\frac{5}{16}''$	$\frac{9}{16}''$	$\frac{9}{16}''$	$\frac{7}{16}''$	$\frac{3}{4}''$	$\frac{15}{32}''$
$9\frac{1}{2}$	$4\frac{3}{4}$ TO $5\frac{1}{8}$	$2\frac{5}{8}$	$5\frac{9}{16}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{15}{32}$
10	$4\frac{7}{8}$ TO $5\frac{1}{2}$	$2\frac{7}{8}$	$5\frac{3}{4}$	$\frac{5}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{15}{32}$	$\frac{3}{4}$	$\frac{15}{32}$
$10\frac{1}{2}$	$5\frac{1}{8}$ TO $5\frac{3}{4}$	3	$5\frac{15}{16}$	$\frac{3}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{17}{32}$	$\frac{13}{16}$	$\frac{17}{32}$
11	$5\frac{3}{8}$ TO 6	$3\frac{1}{4}$	$6\frac{1}{8}$	$\frac{3}{8}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{17}{32}$	$\frac{13}{16}$	$\frac{1}{2}$
$11\frac{1}{2}$	$5\frac{3}{4}$ TO $6\frac{1}{4}$	$3\frac{1}{2}$	$6\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{19}{32}$	$\frac{13}{16}$	$\frac{1}{2}$
12	6 TO $6\frac{1}{2}$	$3\frac{5}{8}$	$6\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{19}{32}$	$\frac{13}{16}$	$\frac{1}{2}$

DATA FOR DESIGNING TIE PLATES



Ribs not exceeding ¼ inch deep are desirable on bottom of plate.

Thicknesses shown are exclusive of any ribs or corrugations on bottom.

On hardwood ties, widths of 7 inches or 7½ inches are recommended.

If splices are slotted for spiking, spike holes in tie plates shall be located accordingly.

Spike holes shall be made the size of the spike plus ⅛ inch, and in high carbon hot worked plates, spike holes shall have a fillet radius of $\frac{1}{16}$ inch.

Plates may be rolled with a camber or crown of $\frac{1}{16}$ inch if desired by the purchaser.

Where plate is cambered or crowned the shoulder height, $\frac{5}{16}$ inch, is measured at center of plate.

For extra heavy service add ⅛ inch to dimensions D and E.

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[17] Adopted, Vol. 27, 1926, pp. 660, 1373.

[18]ANTI-CREEPERS

GENERAL REQUIREMENTS TO BE MET IN THE DESIGN AND MANUFACTURE

(1) Anti-creepers shall be so designed as to fit two or more different weights of rail and so that they can be readily removed and reapplied.

(2) They must be easy to apply under full-ballasted track.

(3) They must be substantial enough to stand driving to place without chance of breaking.

(4) The least possible number of movable parts is desirable.

(5) When applied they must be in position rigidly enough to carry the tie with them in any kind of ballast without slipping.

(6) They shall be made with sufficient take-up to permit of proper tightening.

(7) When in place they must not loosen sufficiently to render them inoperative when the rail slacks back.

(8) Controlling or delicate parts should be made of non-rustable material.

(9) Anti-creepers made of steel shall be of sufficient size to minimize their destruction by rust.

(10) Anti-creepers made of malleable iron must be from furnace malleable iron properly annealed, and of sufficient weight to prevent breakage and distortion in application or in service.

[19]SPECIFICATIONS FOR SOFT STEEL CUT TRACK SPIKES

(I) MANUFACTURE

1. The steel may be made by the Bessemer or Open-Hearth process, or both.

(II) CHEMICAL PROPERTIES AND TESTS

2. (a) The steel shall conform to the following requirements as to chemical composition:

	Bessemer	*Open-Hearth*
Carbon, per cent not under............	0.06	0.12

(b) A carbon determination shall be made of each melt of Bessemer steel and three determinations shall be made every 24 hours, one for each 8-hour turn, respectively, representing the average carbon content in the steel. These analyses shall be made from drillings taken at least ⅛ inch beneath the surface of a test ingot obtained during the pouring of the melts. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

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[18] Adopted, Vol. 14, 1913, pp. 107, 1066.

[19] Adopted, Vol. 27, 1926, pp. 636, 1367.

(c) An analysis of each melt of open-hearth steel shall be made by the manufacturer to determine the percentage of carbon. This analysis shall be made from drillings taken at least $\frac{1}{8}$ inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

(III) PHYSICAL PROPERTIES AND TESTS

3. (a) The body of the full size finished spikes shall bend cold through 180 degrees flat on itself, without cracking on the outside of the bent portion.

(b) The head of the full size finished spikes shall bend backward to the line of the face of the spike, without cracking on the outside of the bent portion.

4. One bend test of each kind shall be made from each lot of 5 tons or fraction thereof.

(IV) WORKMANSHIP AND FINISH

5. (a) The spikes shall conform to the dimensions specified by the purchaser with the following permissible variations.

(b) A variation of $\frac{1}{32}$ inch over and $\frac{1}{64}$ inch under the specified cross-section dimensions of the body of the spike will be permitted.

(c) A variation of $\frac{3}{32}$ inch over and $\frac{1}{32}$ inch under the specified dimensions of the head of the spike will be permitted.

(d) A variation of $\frac{1}{8}$ inch from the specified length of the spike measured from the under side of the head to the point will be permitted.

(e) A variation of one degree in the specified angle of the under side of the head of the spike will be permitted.

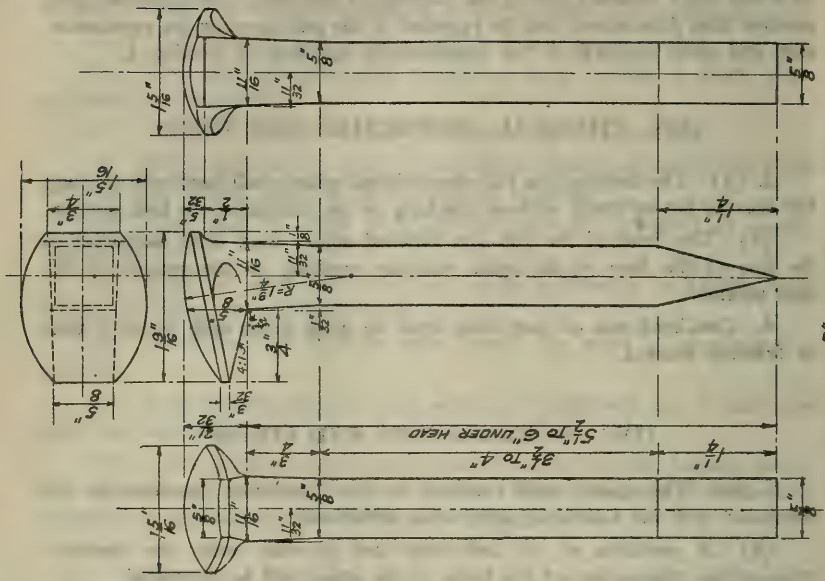
6. The finished spikes shall be free from injurious defects and shall have a workmanlike finish.

(V) INSPECTION

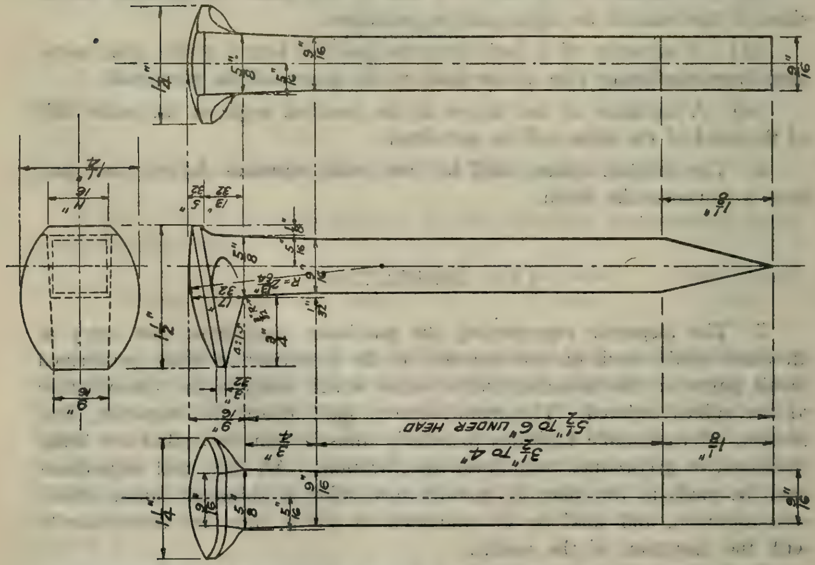
7. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed to all parts of the manufacturer's works which concern the manufacture of the spikes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy himself that the spikes are being furnished in accordance with these specifications. All tests and inspections shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

8. Spikes which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

[20]DESIGN OF CUT TRACK SPIKE



DESIGN OF 5/8" CUT TRACK SPIKE.



DESIGN OF 9/16" CUT TRACK SPIKE.

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[20]Adopted, Vol. 22, 1921, pp. 653, 972.

[21]SPECIFICATIONS FOR STEEL SCREW TRACK SPIKES

(I) MATERIAL

Process

1. The steel may be made by the Bessemer or Open-Hearth process.

Finishing

2. The heads of the spikes shall be formed and the threads rolled at a temperature not less than 750 degrees Cent.

(II) PHYSICAL REQUIREMENTS

Tension Tests

3. The full-sized finished spikes shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	60,000
Yield point, lb. per sq. in.	0.5 tensile strength
Elongation in two inches, per cent	20.

Bend Tests

4. The full-size finished spikes shall bend cold through 90 degrees around a pin the diameter of which is equal to three times the diameter of the spike, without cracking on the outside of the bent portion.

Number of Tests

5. (a) One tension and one bend test shall be made from each lot of 100 kegs or fraction thereof.

(b) If any spike tested develops flaws, it may be discarded and another spike substituted.

Retests

6. (a) If the percentage of elongation of any tension test spike is less than that specified in Section 3, a retest shall be allowed.

(b) If any tension test spike breaks more than ¾ inch from the center of the gage length, a retest shall be allowed.

(III) DESIGN

Workmanship

7. The spike shall conform to the dimensions specified by the purchaser. The head shall be concentric with, and firmly joined to the body of the spike. The threads shall be sharp and true to gage and of the pattern specified by the purchaser. A variation of $\frac{1}{32}$ inch over the specified

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[21] Adopted, Vol. 21, 1920, pp. 181, 1369.

diameter of the unthreaded portion of the body of the spike will be permitted. A variation of 1/32 inch over the specified diameter of the threaded portion of the spike will be permitted. A variation of 1/16 inch under and 1/8 inch over in the reach of the head of the spike will be permitted. A variation of 1/8 inch from the specified length of the spike will be permitted.

(IV) MANUFACTURE

Finish

8. The finished spikes shall be free from injurious defects and shall have a workmanlike finish.

Marking

9. A letter or brand indicating the manufacturer shall be pressed on the head of the spike while it is being formed.

(V) INSPECTION

Inspection

10. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the spikes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the spikes are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

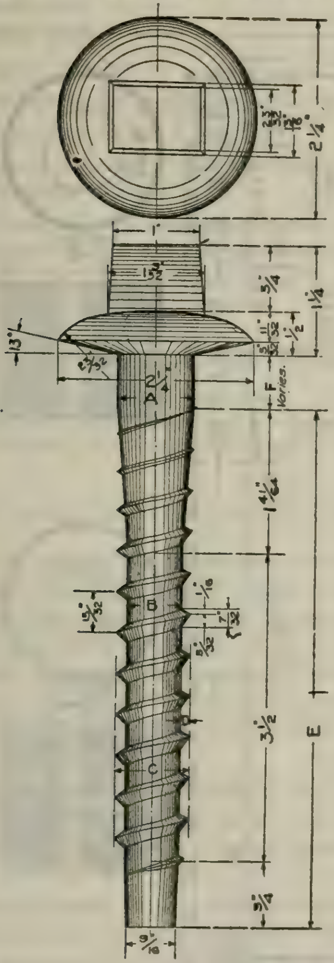
11. Spikes which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

(VI) SHIPMENT

Packing

12. When spikes are shipped they shall be properly oiled to prevent rusting and shall be packed in good, serviceable packages. All packages shall be plainly marked as to material, size of spike and name of manufacturer, unless otherwise specified.

[22]DESIGN OF SCREW SPIKE



	LETTER	MAX.	STAND.	MIN.
Under Head	A	$\frac{29}{32}$	$\frac{7}{8}$	$\frac{7}{8}$
Root	B	$\frac{21}{32}$	$\frac{5}{8}$	$\frac{5}{8}$
Over Thread	C	$\frac{29}{32}$	$\frac{7}{8}$	$\frac{7}{8}$
Thread	D	$\frac{9}{64}$	$\frac{1}{8}$	$\frac{1}{8}$
Length	E	$6\frac{1}{64}$	$5\frac{57}{64}$	$5\frac{49}{64}$
Length Under Head	F	Varies according to thickness of Rail Base and Tie Plate		

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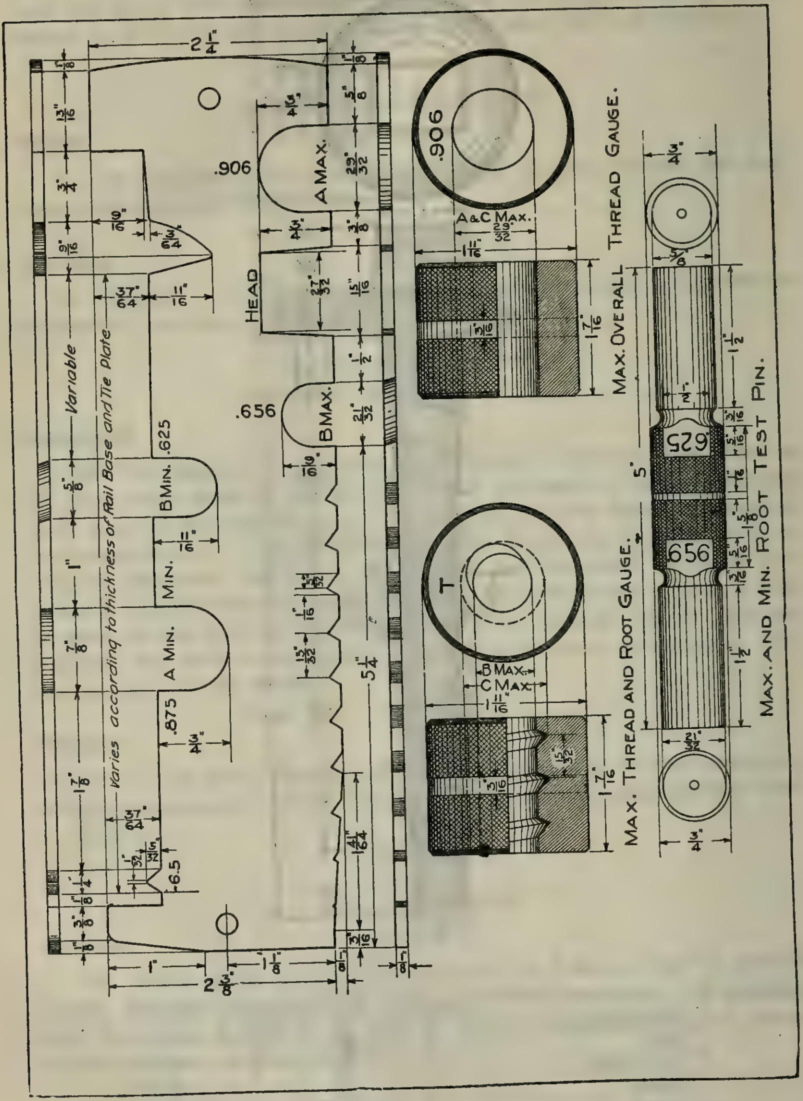
[22]Adopted, Vol. 18, 1917, pp. 428, 1488.

[23]TESTING GAGE FOR SCREW SPIKE



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[23] Adopted, Vol. 18, 1917, pp. 429, 1488.

[24]OILING TRACK FIXTURES

The following is recommended as good practice:

(1) Oiling track bolts.

(2) Oiling splice bars.

(3) Oiling turnout fixtures.

(4) Oiling rail, tie plates and spikes when subjected to special corrosive conditions when ultimate life is affected.

(5) Oiling to be done twice a year—preferably in May and October, and only when the material is dry.

(6) Oiling of rail, tie plates and spikes to be done by machine; other materials by brush; new track bolts and joints to be oiled before applying.

(7) Satisfactory oil for this purpose should conform to the following general specifications:

ASPHALT BASE DIPPING OIL SPECIFICATIONS

Flash point, minimum	130 degrees Fahr.
Asphalt, 100 penetration, minimum	45%
Viscosity, Saybolt Universal, 130 degrees Fahr.	240-350 seconds

[25]SPECIFICATIONS FOR THE LAYING OF NEW TRACK

1. The work covered by these specifications will include the laying and ballasting of the tracks mentioned, ready for the operation of trains.

2. The Railway Company's authorized representative shall arrive at a clear understanding with the Contractor as to the force to be employed and the speed with which the work shall proceed. Prior to starting the work the Contractor shall notify the Railway Company's representative a sufficient time in advance so that adequate arrangements can be made for the prosecution of the work.

3. The Railway Company will furnish all track materials on cars (or on the ground in the material yard at ....).

4. The Contractor shall provide all tools needed in connection with this work.

5. The Railway Company will provide the necessary inspector or inspectors and the instructions of such inspectors regarding the quality and type of work to be done shall be complied with at all times by the Contractor.

6. The Contractor shall supply the necessary foremen and labor to prosecute the work properly and in such numbers as may be required by the Chief Engineer or his authorized representative, and at the request of the Chief Engineer or his representative will remove any foreman or man not satisfactory to the Railway Company.

7. No track shall be laid and no track materials shall be placed on the roadbed until the subgrade shall have been constructed and finished to true planes according to the stakes set by the representative of the Railway.

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[24] Adopted, Vol. 24, 1923, pp. 502, 1167.

[25] Adopted, Vol. 24, 1923, pp. 457, 1166.

8. The Railway Company's representative shall set all center and grade stakes, which stakes shall be followed by the Contractor in lining and surfacing track.

9. ....Hewn or .... sawn ties shall be laid in each 39-ft. panel in main tracks and .... ties shall be laid in each 39-ft. panel in side and yard tracks. They shall be spaced uniformly and laid at right angles to the rail with the ends lined uniformly as may be specified.

10. Ties must be laid with the heart side down.

11. Ties must be adzed carefully, giving full bearing with the least possible cutting of ties. The bottom of the rail, the tie plate and the bearing surface of the tie shall be cleaned before the rail is laid.

12. Tie plates, when furnished, must be applied in a workmanlike manner at time rail is laid to avoid unnecessary spiking and must be so placed that the shoulder is in contact with the base of rail or the splice bar for the entire length of the shoulder.

13. Metal expansion shims must be used to provide for the proper openings between the rails and a thermometer shall be used to determine the thickness of the shims to be used, in accordance with the standards of the A.R.E.A.

14. Necessary gaging must be done at the time rail is laid and should conform to the Railway Company's standard practice.

15. All joints must be full bolted and rail drilled where necessary.

16. All bolts must be tightened before track is turned over to operation.

17. In laying rail on tangents the staggering of joints must be provided and in laying rail on curves care must be taken to put in short length rails at proper intervals in the low rail and to maintain the proper stagger throughout the curve.

18. As far as possible all joints should be kept out of street and road crossings.

19. Rails must be fully spiked to each tie in accordance with the standards of the Railway. The inside and outside spikes shall be as far apart as the face and character of the tie will permit. The inside spikes shall be on the same side of the tie.

20. All spikes shall be started and driven vertically and square with the rail and so driven that the face of the spike shall have a full hold on the base of the rail.

21. On bridges and trestles no spikes shall be driven in slots or against the ends of the angle bars, neither should track be anchored to the bridge in any way.

22. Rail anchors shall be applied in accordance with the standards of the Railway Company at the time the track is laid. Care should be taken to give them a firm bearing against the ties when installed.

23. On curves the outer rail shall be given superelevation according to the Railway Company's standard practice.

24. All switches, frogs and guard rails must be placed in accordance with the Railway Company's standards.

25. Switches must be left in proper adjustment, special care being given to the bending of the stock rail.

26. The Railway Company shall furnish all ballast as required and shall transport and switch such ballast free of cost to the Contractor to the point where it is to be applied.

27. Ballast shall be unloaded by the Contractor by dumping or plowing as the means provided by the Railway Company permit. If the ballast is in center dump cars it shall be unloaded by having one or more cars opened at a time, allowing the required amount of ballast material to flow out as the train is moved along slowly. If the material is on flat or open cars, it shall be plowed off by means of an unloading machine while the train is moving at such a rate of speed as to provide the desired amount of material as uniformly distributed as possible. The unloaded material shall be leveled down by means of a ballast plow or spreader. Care shall be taken not to destroy or disturb the grade stakes.

28. The preliminary surfacing gang shall follow the unloading as closely as the regularity of the ballast supply will permit. In using jacks, they must be placed close enough together to prevent undue bending of the rail or strain on the joints. Both rails must be raised at one time and as nearly uniformly as possible. The track shall be so lifted that after a period of not less than three days after the last lift it will be necessary to give it a final lift of not less than one inch nor more than two inches to bring it to the grade of the stakes. All ties that are pulled loose shall be replaced to proper position and must have a bearing against the rail and be fully spiked, with all spikes driven home before tamping. Spikes must not be straightened while being driven. Ballast shall be well packed or tamped with pick, shovel, tamping bar or tamping machine, as directed, from a point 15 inches inside of each rail on both sides of the ties to the end of the ties, tamping the outside of the tie first.

29. When the track has been raised to within one or two inches of the final grade and properly compacted by traffic, a finishing lift shall be made by jacking up the track to the exact height provided for by the grade stakes. All allowance for settlement shall be taken care of in the setting of the stakes and the necessary ballast forked or shoveled in, and then driven to place by tamping machines, tamping picks, bars or shovels, as directed by the proper representative of the Railway Company. In making the finishing lift the spot board and level board must be used with care and the track brought to a true surface.

30. The track shall be placed in good alinement before the finishing lift is made, but a lining gang shall follow one or two days behind the finishing lift and shall spot up all places found not holding up to proper surface, and shall line the track to accurate alinement. Stakes shall be set for the alinement before the finishing lift is made and the final alinement must conform to the stakes.

31. The Contractor shall trim the ballast to conform to the standard roadbed section, and the Railway Company for this purpose shall supply its standard cross-section template. The portion of the subgrade outside the ballast line shall be left with a full even surface and the shoulder of the embankment properly dressed to the standard roadbed section. The Contractor shall dispose of any surplus ballast after trimming the ballast section as directed by the representative of the Railway Company.

32. If as the work proceeds ballasting shall lag behind the track laying or if for any other cause the track shall require a running surface to prevent the bending of rails or injury to the track by reason of trains being operated over the track at moderate speeds, such work shall be done on the written order of the representative of the Railway who shall specify the stations between which such work shall be done.

33. The Contractor shall install and secure promptly all stockguards, crossing plank and similar facilities adjacent to or forming a part of the track.

34. The Contractor shall remove from the Railway Company's property all rubbish and waste from the work, or dispose of it as directed by the representative of the Railway Company. After completing the work the Contractor shall remove from the Railway Company's property, and from all public and privately-owned property, at his own expense, all temporary structures and waste resulting from his camping operations.

35. The Contractor is to understand that any work not specifically mentioned in the specifications, but which is necessary, either directly or indirectly, for the proper carrying out of the intent thereof, shall be required and applied, and he shall perform all such work just as if it were particularly delineated or described. Unless specifically mentioned above, all work shall conform to the standards of the Railway Company.

COMMITTEE VI

BUILDINGS

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[1]DEFINITIONS

Ashpit.—A structure into which cinders are deposited from locomotives, for subsequent removal.

Coaling Station.—An established location for the storing and delivering of coal to locomotives.

Drop Pit.—A pit in the track inside of the engine house in which machinery is located for dropping wheels from under locomotives.

Engine House.—A structure for housing and the general maintenance of engines in service.

Engine Pit.—A pit in the track inside the engine house to facilitate the repairing and cleaning of the running gear under an engine.

Freight House.—

- **Inbound.**—A building for the handling of freight for delivery to consignee.
- **Outbound.**—A building for the receiving of freight by the railroad for shipment.

Inspection Pit.—A pit in a track approaching an engine house to facilitate the inspection of engines.

Oil House.—A building for the storage and distribution of oil and waste.

Power House.—A building for housing apparatus for generating light, heat and power for various purposes.

Rest House.—A building for the accommodation of employees, usually containing rest and recreation rooms, sleeping quarters, lunch room, lockers, bath, etc.

Section Tool House.—A building for housing of section cars, tools and small track material.

Shelter Shed.—

- **Butterfly Type.**—A type of structure erected over platforms for protection from the weather with a central line of supports and roof sloped towards center for drainage.
- **Umbrella Type.**—A type of structure erected over platforms for protection from the weather with a central line of supports and roof sloped to the sides for drainage.

Shop Buildings.—Various structures for the construction and repair of locomotives, cars and other railway equipment.

Smoke Jack.—A ventiliating appliance for taking smoke and gases out of engine houses.

Station.—An established location for the accommodation of passenger and freight traffic.

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[1] Adopted, Vol. 21, 1920, pp. 146, 1362.

Transfer Platform (Freight.)—A platform approximately level with freight car floors used in transferring freight from car to car.

Transfer Table.—A traveling structure with a track on which a locomotive or car can be run and transferred from one parallel track to another.

Turntable.—A revolving structure for turning locomotives or cars.

Turntable Pit.—A circular pit depressed below the surface of the ground in which the turntable revolves.

[2]PASSENGER STATIONS

Passenger Stations with One General Waiting Room

The use of one general waiting room for a passenger station (without reference to separate waiting rooms for colored people) is recommended as good practice for the following reasons:

(1) It permits the general waiting room to be properly proportioned.

(2) It permits proper development of a retiring room for women, with private entrance to the lavatory.

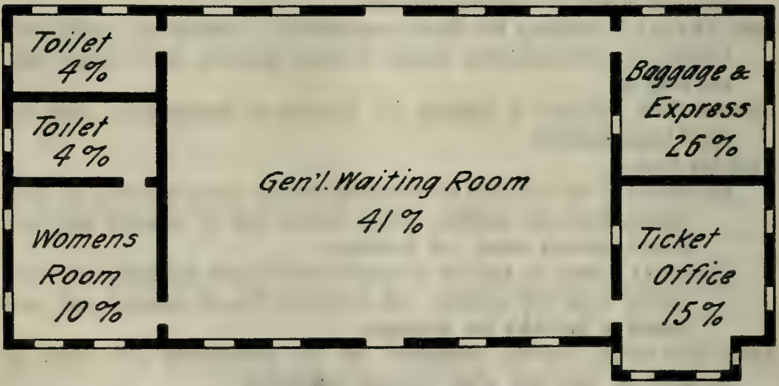
(3) It readily admits of the other rooms being properly proportioned.

(4) It permits ease of access from the agent's office to the trains, to the baggage room and to the waiting room.

(5) It permits the ticket office to be of proper size and location for general office purposes.

(6) It admits of the station being contracted in sizes without detriment to facilities.

(7) It offers economy in heating.



Division of Floor Area Recommended for Passenger Stations with One General Waiting Room

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[2] Adopted, Vol. 6, 1905, pp. 682, 684, 690; Vol. 11, Part 2, 1910, pp. 1022, 1023, 1049; Vol. 16, 1915, pp. 739, 780, 1149, 1151; Vol. 19, 1918, pp. 265, 1091; Vol. 20, 1919, pp. 211, 213, 870; Vol. 28, 1927, pp. 661, 1414.

Heating

Method of, for Medium-Sized Stations

Stations with one or two waiting rooms, and an office, can be heated satisfactorily and economically by the use of stoves, especially where it is not necessary to maintain an even temperature throughout the entire day. The danger of fire from the use of stoves should be guarded against as much as possible.

Where two or more waiting rooms separated by an office are to be heated, a single central heating plant, preferably in the basement, is recommended as being the most economical and satisfactory. For such a heating plant a hot water, steam or hot air furnace may be used. The hot air furnace constitutes a greater fire risk than either the steam or hot water heater. An even temperature is more easily maintained by hot water than by steam, but a station is more quickly heated with a steam system than with a hot water system. The pipes and radiators of a hot water system must be kept above a freezing temperature.

Lighting

Electricity is the safest, most satisfactory and desirable method of lighting, and such lighting should be installed in all stations where reliable current is available at reasonable cost.

It is recommended that all wiring be installed in rigid metal conduit.

Circuits should be arranged so that lights may be controlled with the view to the minimum consumption of current, consistent with comfort, convenience and safety, and so that the controlling devices will be accessible to those employees who are responsible for the economical operation of the lighting system.

The intensities of illumination recommended for the various portions of a station are given in the following table:

Waiting rooms	2 to 4 foot candles
Rest rooms, toilet and smoking room	1 to 3 foot candles
Ticket office	6 to 10 foot candles
Concourse	1 to 2 foot candles
Baggage room	3 to 6 foot candles
Train platforms	0.5 to 1 foot candles

Fixtures should be selected which will give the desired intensity of properly diffused light without glare.

For waiting rooms, ticket offices, rest rooms, toilet rooms, smoking rooms and concourses, indirect or semi-indirect lighting is recommended, with fixtures attached to the seats, where practicable, where ceilings are high.

For baggage rooms and covered train platforms, direct lighting fixtures equipped with enameled iron reflectors will generally prove satisfactory and economical.

For illuminating uncovered train platforms, the use of flood lights should be considered, providing they can be installed without producing a glare that will be objectionable and dangerous to train crews.

Platforms (High Platforms at Passenger Stations)

It is recommended that high platforms be provided only in connection with tracks devoted exclusively to passenger traffic.

Sanitary Provisions for Stations

In all stations different planes should be connected by curves; all heads and angles that may collect dirt and protect disease germs should be avoided; and sufficient artificial light should be provided, as dark places are the ones that collect dirt and filth.

Shelter Sheds

In that part of the country where heavy snow occurs the Umbrella type of shed is preferable though somewhat more expensive in first cost.

In that part of the country where heavy snows are not a factor, the Butterfly type of shed is preferable.

Stairways and Ramps

Stairways and steps shall be avoided where ramps can be used.

Ramps for pedestrian use only, with wearing surfaces properly treated with a non-slip material, and constructed on grades under twelve per cent, are recommended as good practice.

Treads of stairways should be provided with safety treads or treated with a non-slip surfacing material.

Widths of treads for stairways used by the public shall be not more than 13 inches, nor less than 11 inches in width, and risers not more than 7 inches nor less than 6 inches in height, the sum of 2 risers and one tread shall be between 25 and 26 inches. The width of treads shall be taken as the horizontal distance from face to face of risers.

Where stairways require more than 16 risers, provide intermediate landings, keeping the length of single flights as near 10 or 12 risers as possible. Use no steps with less than three risers. Where used, nosings on treads should be limited to a projection of one inch.

Make width of landings in direction of travel not less than 4 feet.

Where practicable, provide same height of risers and same width of treads for all stairways used by the traveling public in any one building.

Risers and stringers should be of closed construction.

Provide ample natural and artificial light for all stairways, avoiding glare and shadows.

Provide hand rails on both sides of all stairways and center hand rails on stairs 8 feet wide. Place top of hand rail 34 inches above tread, measured on line of face of risers and keep center line of hand rails at least 5 inches from side walls, or 8 inches center to center for intermediate hand rails.

Stairways and ramps should be located conspicuously in main lines of travel, with ample space at top and bottom for crowds to disperse without confusion.

[3]LOCATION AND DESIGN OF SIGN FOR PASSENGER STATIONS

At flag stations or small stations without canopies it is recommended that one sign facing the track be installed, this being considered sufficient.

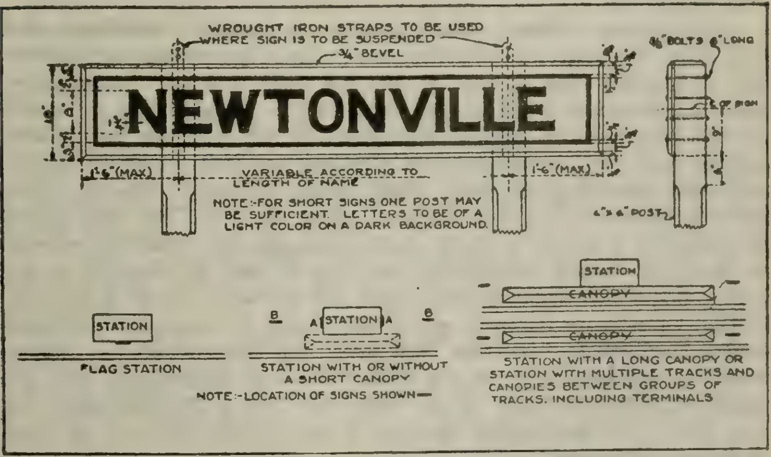
At larger stations without or with a short canopy it is recommended that signs be installed as follows:

(a) On each end of the building and at right angles to the track, bearing in mind visibility from the air.
(b) Signs erected on posts at some distance from each end of the building and parallel to the track.
(c) At junctions, or for some special reasons, it may be desirable to erect signs as recommended under both (a) and (b).

At stations with a long canopy, or stations with multiple tracks and canopies between groups of tracks, including terminals, it is recommended that sufficient signs be erected on posts beyond the ends of the canopies and parallel to the tracks. At such stations the character of the main buildings is usually such that an ornamental architectural name on the building should be sufficient.

The use of built-up signs with letters of a light color on a dark background is recommended, and care should be exercised to use a background of a dull or non-reflecting surface. Blue or black smalts give very good results in this respect. The showing of distance from main terminals or other information on station signs is not recommended.

The diagram illustrates the recommended uses of signs and a type of built-up sign.


WROUGHT IRON STRAPS TO BE USED WHERE SIGN IS TO BE SUSPENDED
3/4" BEVEL
NEWTONVILLE
3/8" BOLTS 6" LONG
℄ OF SIGN
1'-6" (MAX)
VARIABLE ACCORDING TO LENGTH OF NAME
1'-6" (MAX)
NOTE:-FOR SHORT SIGNS ONE POST MAY BE SUFFICIENT. LETTERS TO BE OF A LIGHT COLOR ON A DARK BACKGROUND.
6"x 6" POST
STATION
CANOPY
CANOPY
STATION
B
A
STATION
A
B
STATION
FLAG STATION
STATION WITH OR WITHOUT A SHORT CANOPY
NOTE:-LOCATION OF SIGNS SHOWN—
STATION WITH A LONG CANOPY OR STATION WITH MULTIPLE TRACKS AND CANOPIES BETWEEN GROUPS OF TRACKS. INCLUDING TERMINALS

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[3] Adopted, Vol. 27, 1926, pp. 1090, 1421.

*FREIGHT HOUSES

Recommended Practice Governing the Design of Inbound and Outbound Freight Houses

General

Separate houses for inbound and outbound freight should be provided where the volume of freight handled will justify the investment.

The outbound house should be not more than 30 feet wide and the inbound house should be from 40 to 60 feet wide.

Where but a single house is needed a width of from 30 to 40 feet is good practice.

In large cities consideration should be given to providing, above the inbound house, one or more floors which may be advantageously leased to shippers for storage purposes.

Materials

In general this type of freight house should be built of fireproof materials throughout. Where economy in the initial investment makes necessary the use of frame buildings, these should have filled floors between masonry foundation walls, and should be divided into sections by fire walls spaced not more than 200 feet apart. The superstructure should be designed to conform as nearly as possible with slow burning construction.

Fire Walls

Where fire walls are necessary they should conform with the Underwriters' requirements for thickness and height and should have tees at the ends and fireproof aprons where the house has combustible side platforms. Openings in fire walls should be as limited in number as possible. No opening should have an area greater than 80 square feet and each opening should be equipped on each side with standard automatic fire doors.

Fire Protection

(a) General.—Where water pressure is available, standpipes and hose racks not more than 150 feet apart should be provided for fighting fire. By putting them on the fire and end walls they are thought to be more accessible and less liable to be blocked by freight than if located at other points, but by putting them about 44 feet from the end of each section, fewer hose connections are necessary to cover the entire station. The valve controlling the water supply should be located below the frost line and controlled by a stem extending above the floor. The valve should be located in a pit, so as to be readily accessible for repair or renewal. It should be drained into the pit, and this in turn be connected to the sewer. A 2½ inch standpipe of wrought iron should be run up to approximately 8 feet above the floor, and to this should be attached a hose rack, equipped with 50 feet of 2-inch linen hose. The Underwriters now recommend 1½-inch hose wherever it is to be handled by inexperienced men, but provision should be made on the water line for a 2½-inch outlet for city hose; care being taken that the threads on the outlet are the same as the city equipment.

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*Adopted, Vol. 15, 1914, pp. 710, 1099; Vol. 16, 1915, pp. 751, 1150; Vol. 18, 1917, pp. 815, 1529; Vol. 27, 1926, pp. 1063, 1420; Vol. 28, 1927, pp. 660, 1414.

(b) Chemical Extinguishers.—Chemical extinguishers should be provided in addition to the hose and standpipes. As they are put out of service by freezing, some provision should be made for replacing them or keeping them warm. Tanks containing a solution of calcium chloride are used successfully.

(c) Red Light.—In houses where electricity is available there should be over each hose rack a small red light to designate the location of the fire-fighting apparatus, this light to be kept burning at all times.

(d) Watchman's Clock.—Where a watchman is employed, a watchman's clock system, with stations located at various points throughout the building, should be employed.

Floors

(a) The type of floor used should conform with the requirements given elsewhere in this Manual under the recommended practice for "Floors for Freight Houses."

(b) Floors should be sloped across the house in the direction of trucking at the rate of 1 inch in 8 feet. Outside platforms should slope away from the building at the same rate.

(c) On the street side of the inbound house, the floor should be from 3 to 4 feet above the street grade, depending on the type of trucks generally in use. On the street side of the outbound house, the height of the floor above the street grade should not exceed 3 feet.

Fenders

On the driveway side of all freight houses, suitable longitudinal wooden fenders should be provided to protect the walls from damage by trucks and wagon wheels.

The fenders should be designed so that they can be readily renewed and should preferably be kept about 2 inches from the walls of the building by separators.

Platforms

(a) Platforms along the track side of the house eliminate the necessity of spotting cars at doors and of keeping open a trucking aisle inside the house on the track side. Such platforms should be not less than 8 feet wide where hand trucks are used, and not less than 12 feet wide where electric trucks are used.

In locations where the winters are long and severe, the elimination of outside platforms with the consequent spotting of cars at doors, is sometimes desirable.

Where outside platforms are omitted, the width of houses should be increased to provide space for trucking aisles.

(b) For loading and unloading machinery and other large bulky packages, platforms should be built, usually as extensions to the inbound and outbound houses, with ramps on the ends of the platforms.

The extension platforms should be at least 8 feet wide, and if possible 16 feet wide, especially if covered. A stub-end track abutting against a platform with a ramp is valuable.

(c) Where both outbound and inbound houses are arranged in the same layout a transfer platform is usually included. One of the best designs for covering these platforms is a butterfly shed, with the posts located in the center of the platform. Where this design is used the platform should not be less than 12 feet wide, to provide room for trucks between the posts and the cars.

Roofs

(a) Where State laws permit, protection over the cars is often used. This should be at least 17 feet above the top of rail, and should preferably extend to within 18 inches of the middle of the car. This will allow walking on the top of cars.

(b) The platforms should be protected by an overhanging roof, not greater than the width of the platform and at least 10 feet above the platform level.

(c) There should also be an overhanging roof, or other protection on the team side to protect goods while being unloaded, the overhang to be at least 4 feet and preferably more, 12 feet at least being needed to give protection from a driving rain.

On account of merchandise being piled high on trucks, it is desirable to have at least 14 feet above the level of the driveway.

Posts

It is desirable to have the floors of freight houses entirely free from posts, but in houses approaching 50 feet in width, the saving made by using posts becomes considerable and great enough to offset the advantages due to their omission.

Cranes

Where no gantry crane is provided in the freight yard, a stiff leg or pillar crane should be provided on the end of the extension platform.

Checkers' Stalls

Stalls for checkers should be located at least one in each section. These should be approximately 4 feet 6 inches by 4 feet 6 inches, with a shelf along the back and drawers beneath. Sometimes they are left entirely open in front, and sometimes are closed up and heated, depending on local conditions. Some roads make their checkers' stalls portable, so as to allow them to be moved in case of a special congestion of freight at certain points.

Doors

Several kinds of doors are satisfactory: Counterbalance (either folding or not), rolling shutters and horizontal sliding.

It is advantageous to have as much door opening on the team side as possible. With all types of doors except the last, all of the house can be opened except for the space occupied by posts.

With horizontal sliding doors not more than half of the space can be opened up at one time.

With no outside platform continuous doors should be used, so that an opening can be obtained at any point opposite a car door.

As the freight trucked into the house and cars must pass through the car door, the height of the freight-house door need be little greater than the car door. All door openings should be at least 8 feet high. On the team side a greater height might at times be convenient.

Door jambs in masonry walls should be protected by metal guards to a height of at least 4 feet.

Downspouts

Downspouts should not be located inside the building and in placing them outside they should be properly protected.

Lighting

(a) Artificial Lights.—Artificial light is needed for operation at night and during the late afternoon in the winter, and wherever possible electricity should be used, with wires run according to the specifications of the National Board of Underwriters. One or more lines of light should be run the full length inside the house, and one line over outside platforms.

Another circuit should be run along the face of the platform wall parallel to the track, with outlet boxes not over 44 feet on centers, with socket arrangement for push plug for use in attaching an extension cord to hang inside the car to provide for loading on dark days and at night.

The type of lights will depend somewhat on the height of the ceiling. All lights should be stationary and operated in circuits from conveniently located panel-boards.

The circuits should be carefully planned, so as to allow maximum economy in use of lights.

(b) Natural Light.—Natural light should preferably be provided in the side walls above the doors. Skylights in the roof are expensive to maintain and ineffective, as is also glass in canopies, or on any plane approaching the horizontal.

Offices

In large houses a separate office should be provided for the foreman. If this can be an elevated structure it will save floor space.

In large houses the general office for the clerks and the private office for the agent should be provided by a second story over the inbound house, and in the second story should also be a space for file, records and stationery cases, toilets and locker facilities for clerks. All this should, as far as possible, be in view from the desks of the agent or chief clerk. The cashier and his desk should ordinarily be located on the first floor.

Where possible it is preferable to have in one section the clerks' and agent's offices, the toilet rooms, etc., for the freight handlers and draymen, the room for "over, short and damaged freight," and the cooperage room for repairing broken packages, etc.

In the larger terminals provision may be wanted to care for perishable freight, and when it is provided it should also be located in this section.

Scales

(a) General.—The weighing of package freight at freight houses is very important from a revenue standpoint, and the railroads are installing a greater number of scales, and giving serious consideration to the weighing of all package freight, except possibly standard packages of known weight.

There are some points where practically all the freight handled is of standard package freight, and at such houses very few scales are needed.

(b) Combination Inbound and Outbound Houses.—In layouts where one house handles both inbound and outbound freight, and where the business is heavy and diversified, the scales should be located perferably at every third door opening, or a maximum of 75-foot centers.

Where this number of scales are used they should be ample to take care of outbound weighing. Scales should be located on the driveway side of the house.

(c) Combination Freight and Baggage Rooms.—At small outlying stations, where there is a combination baggage and freight room, a fixed scale with platform level with the freight room floor, located perferably at one side of the door nearest the driveway side, is recommended, as at this point it will be less liable to damage from trunks or large packages.

(d) Separate Outbound and Inbound Houses in Same Layout.—In outbound houses it is desirable to have a scale at every second door opening, or at a maximum of 75-foot centers. These shall be located approximately 6 to 8 feet from the receiving side of the house.

In inbound houses it is desirable to have scales placed at 100-foot centers as the maximum, and located on the receiving side.

(e) Capacity.—Scales for houses handling freight only should have a minimum capacity of four tons. Higher capacity scales cost very little more and are economical from an operating standpoint as they will stand up better under the abuse they are usually subjected to.

At combination freight and baggage rooms a fixed scale level with the freight house floor, with a minimum capacity of two tons is recommended.

(f) Location.—The ideal location for scales is to so place them that freight can be weighed as received and trucked to cars without rehandling.

(g) Platforms.—In large houses scale platforms should be as small as will be practicable to accommodate the trucks used, and usually not over 6 feet by 8 feet, except at certain localities, where one or two large scales are necessary to handle freight that is especially bulky.

(h) Type of Scale.—Where a large volume of freight is handled during short periods, dial attachments to scales are recommended, as the additional cost of installation and maintenance is justified by the increased amount of freight that can be handled.

Where the volume of freight handled during short periods is not large, beam scales are preferable.

Tracks

Distance to Center Line of Track.—The distance from the center of the nearest track to the face of the platform or freight house should be not less than 5 feet 9 inches, where tracks are on tangents.

Distance Platform to Top of Rail.—The top of rail should be not more than 4 feet below the floor or platform level at the track edge, where refrigerator cars are not to be handled in any quantity. With occasional refrigerator cars the doors can be opened before the cars are set.

Where refrigerator cars are to be handled regularly, the height should not be more than 3 feet 8 inches, this conforming to the recommendation of the M.C.B. Association. (See M.C.B. Proceedings for 1911, Vol. 45, page 728.) Many roads are building cars that are lower than the maximum figures given above, and each road, in deciding the height of platform above the top of rail, should take into consideration the sizes of cars that predominate on its line.

[5]ICE HOUSES AND ICING STATIONS

Icing stations may be built to handle (1) natural ice, (2) artificial ice, and (3) a combination of both natural and artificial ice. Provision must be made at many plants for the handling of a certain amount of crushed ice.

They may be divided into two classes, according to the method used to handle the ice, namely, gravity stations and mechanical stations.

The method of operation indicates the general design to be used in construction. Gravity plants are much cheaper to build than are mechanical plants, but are slower in operation.

The design selected, either gravity or mechanical, should be one in which the ice is always under control, so there will be no collision of the cakes in transit, thus avoiding delays and loss of ice by breakage. Back travel and duplicate handling of the ice should be avoided.

The location of the house, number and arrangement of rooms and locations of platforms and machinery require careful study so as to assure economical and rapid operation both in filling the house and icing cars.

Where natural ice is harvested houses are filled by means of portable slides, made up in sections and laid on the ground from the source of supply to the foot of a motor-driven elevator at the house. If the local ice supply is not sufficient or if the station is entirely dependent upon ice shipped in, a platform, at car floor height, must be provided along the track side of the house. This platform may be used in loading ice for shipment as well as for handling ice to storage.

Where large capacity is required it is desirable to build the house higher rather than to spread it out. Heights from 18 to 36 feet are generally used.

To prevent rise of temperature, due to heat passing through the ground, some of the storage space should be below the grade line, extending about a foot below frost line, if drainage is obtainable.

Ice houses are generally of frame construction with a gable roof. The side walls of the storage house should be so constructed as to afford maximum insulation. If a concrete foundation is not provided, the walls should be tied together at the bottom with rods to prevent spreading. These rods should be below the floor line to avoid obstruction. In the storage portion of the house the use of interior supporting members should be avoided, as they interfere with the handling of the ice. The floor may be wood plank on sleepers set in a cinder bed, concrete on cinders or a combination of concrete and cork, as conditions warrant. Floors should pitch slightly toward the center so that when the house is filled, the ice will not throw any stress on the outside walls. A drain tile should be laid through the center of the house for drainage.

Platforms for icing cars may be single or double-deck. Where single platforms are used the height is generally 13 feet to 16 feet 6 inches above top of rail. Where two-deck platforms are used general practice is to have heights of 13 feet to 14 feet for the lower one and 20 feet to 23 feet for the upper one. Double-deck platforms need not be wider than

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[5]**Adopted, Vol. 27, 1926, pp. 1082, 1421.**

12 feet, as cake ice is handled on the lower one and crushed ice, in two-wheeled carts, on the upper one. Single platforms should be somewhat wider, as both kinds of ice are handled on the same platform. A suitable distance from center line of icing track to the platform is 6 feet. Provision should be made on platforms for a supply of salt. Ample arrangements should be made for lighting so that night operation can be carried on.

At important stations it is desirable to provide two tracks, one on each side of the platform, so that two trains can be iced at the same time.

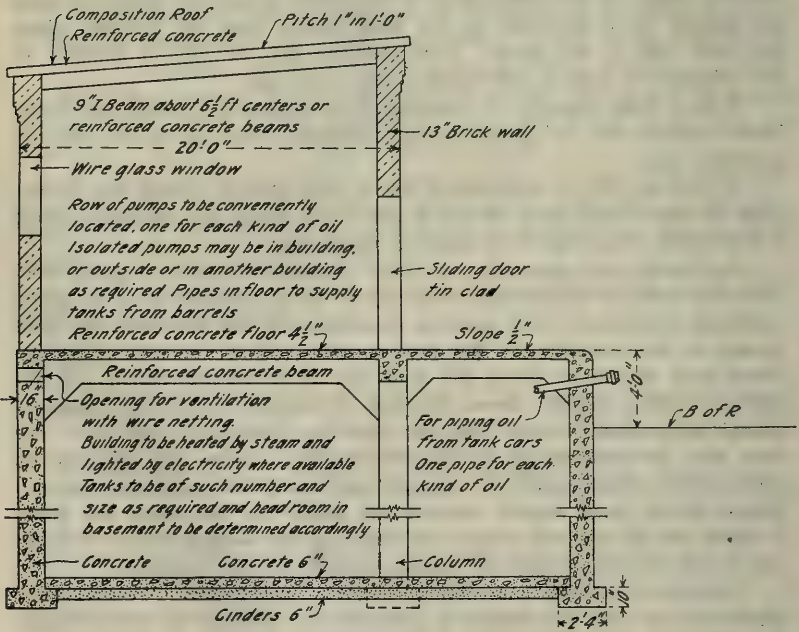
Where operating conditions require it, mechanically operated endless chain platform conveyors and inclines should be installed.

[6]OIL HOUSES

(a) Oil houses at terminals should be separated from other buildings.

(b) Oil houses should be fireproof and the storage in large houses preferably be either underground or in the basement.

(c) Oils that are stored in sufficient quantities should be delivered to the tanks in the house direct from tank cars. For oils that are stored only in small quantities, provision should be made for delivery to storage tanks from barrels by pipes through the floor.


Composition Roof
Reinforced concrete
Pitch 1" in 1'-0"
9" I Beam about 6½ ft centers or reinforced concrete beams
20'-0"
13" Brick wall
Wire glass window
Row of pumps to be conveniently located, one for each kind of oil Isolated pumps may be in building, or outside or in another building as required Pipes in floor to supply tanks from barrels
Reinforced concrete floor 4½"
Sliding door tin clad
Slope ½"
Reinforced concrete beam
16"
Opening for ventilation with wire netting.
Building to be heated by steam and lighted by electricity where available
Tanks to be of such number and size as required and headroom in basement to be determined accordingly
For piping oil from tank cars One pipe for each kind of oil
4'-0"
B of R
Concrete
Concrete 6"
Column
Cinders 6"
10"
2'-4"

Cross-Section of Typical Oil House, 20 by 40 Feet

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[6]Adopted, Vol. 10, 1909, pp. 1127, 1128, 1136, 1140; Vol. 11, Part 2, 1910, pp. 1027, 1037, 1054; Vol. 16, 1915, pp. 745, 1149; Vol. 28, 1927, pp. 660, 1414.

(d) The delivery system from the storage tanks to the faucets should be such that the oil can be delivered quickly and measured automatically. The delivery should also be such that there will be a minimum of dripping at the faucet and that the dripping may drain back to the storage tanks.

(e) Openings for ventilation should be provided above the level of the top of the tanks.

(f) Lighting, when required, should be by electricity and heating by steam.

(g) For fire protection purposes a live-steam line should be run to the oil storage space, controlled by a valve outside the house.

(h) It is necessary to provide sufficient heat in oil houses so that in cold weather the heavy oils can be maintained at a temperature at which they can be pumped.

(i) Where paints and paint oils are carried in oil houses they should be stored in evaporation proof tanks, equipped with agitators.

(j) Lighting fixtures should be of a vapor proof type.

(k) For storing small quantities of oil, paints, etc., the use of rectangular or cylindrical steel tanks, arranged in batteries and located on the main floor of the oil house, is recommended. Such tanks should be equipped with barrel track, and barrel cradles for handling oil from barrels to the tanks and with measuring pumps for delivering oils. Cylindrical tanks should be used for storage of paints which have to be kept mixed and tanks in which paints are stored should be equipped with agitators.

Rectangular tanks are preferable for oil storage on account of requiring less floor space for a given capacity than cylindrical tanks.

The installation of a chain hoist for handling barrels is recommended.

[7]REST HOUSES

Purpose

Rest houses are built to furnish accommodations for trainmen held at terminals away from home. The need of these houses is increasing with the construction of large terminals away from the centers of the town. With them the men can be given clean and satisfactory accommodations, are kept out of temptation, are in better condition for their work, and are close at hand when wanted. The success of the house is dependent very largely upon the manager. With a man having the requisite ability and enthusiasm, the house and its associations can be made attractive and to have a valuable influence.

Location

The rest house should be so located as to be readily accessible, but sufficiently removed from other terminal facilities so as to permit of attractive surroundings.

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[7]Adopted, Vol. 16, 1915, pp. 766, 1151; Vol. 28, 1927, pp. 661, 1414.

Requirements

Rest houses should provide the following facilities and accommodations:

(a) Sleeping rooms.
(b) Locker and lavatory rooms.
(c) Lounge and reading rooms.
(d) Toilet rooms.
(e) Dining or lunch rooms.
(f) Kitchen, pantries and store rooms.
(g) Boiler room and fuel storage.

Sleeping Rooms

Provision should be made for dormitories, or individual sleeping rooms as local conditions may require.

Sleeping rooms should be located as far from lounge rooms, dining rooms and kitchen as possible, but close to lavatory and toilet rooms. They should be well ventilated with outside exposure if possible and designed so that they can be easily and readily cleaned. They should be equipped with comfortable beds, chairs and clothes lockers and space for storing bedding and linen should be provided convenient to them. Shades should be provided for windows.

Locker and Lavatory Rooms

Locker and lavatory rooms should be located convenient to sleeping rooms, and should be readily accessible also for those who wish to use them but who do not desire sleeping accommodations.

Where the extent of the investment will permit, separate lavatory rooms are recommended for the dormitories and for general use.

Lavatory rooms should be equipped with shower baths, wash basins, mirrors for shaving, and the usual accessories that are provided in a modern bath room.

Locker rooms, which should be adjacent to lavatory rooms, or part of the lavatory rooms, should be furnished with metal lockers, benches or chairs, and mirrors.

Locker and lavatory rooms should have impervious floor surfaces, properly waterproofed, and perferably plastered walls.

Floor drains should be provided in floors. Shower bath compartments should be of slate, marble or metal.

Fixtures should be supplied with hot and cold water.

Lounge or Reading Rooms

Adjacent to the lobby should be a lounge or reading room equipped with sufficient furniture and decorations to provide a comfortable, homelike atmosphere, where employees may read, write or rest.

Lobby

There should be but one public entrance. The entrance lobby should be a room large enough to serve as a center for the activities of the building, with an office for the manager, safe for checking valuables, bulletin board, phone booth, etc.

Toilet Rooms

Ample toilet room facilities should be provided, preferably separate facilities for dormitories and for general use convenient to the lobby. These should be designed to conform with the best practice in sanitation, both as to construction and fixtures, and should be well-ventilated and have outside exposures, if possible.

Dining or Lunch Room

Where these facilities are provided they should preferably be located adjacent to the lobby. A lunch counter should be provided, supplemented by tables, if the extent of the project justifies it. The equipment should be durable, sanitary and preferably designed and installed by a manufacturer of such equipment.

Kitchen, Pantries, etc.

A properly designed kitchen with necessary pantries, storerooms, provision rooms, etc., should be provided adjacent to the dining room, furnished with modern, sanitary equipment.

For refrigeration a mechanical refrigeration system is recommended.

Meeting Room

Where the investment will permit, a room should be provided where meetings, lectures, etc., may be held.

Heating

Heating should be preferably by steam furnished from a central or individual heating plant. Where a separate heating plant is necessary, provision should be made for coal storage, and economical removal of ashes.

Lighting

Adequate artificial lighting should be provided, preferably by electricity.

General Construction

In general the building should be of fireproof construction throughout. Fire protection, fire escapes, fire gongs and all the best appliances for fire protection should be provided.

Outside porches are desirable.

In all cases the size of the building and extent of the facilities should be proportioned and designed to meet the particular requirements and local conditions, using the foregoing recommendations as guides rather than rules.

[8]SECTION TOOL HOUSES

Class A

House shall be 14 by 20 feet, with long dimension parallel to track; house shall have sliding door 8 feet in clear at extreme end on track side to permit the storing of handcar.

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[8] Adopted, Vol. 11, Part 2, 1910, pp. 1044-1046, 1054; Vol. 16, 1915, pp. 746, 1149; Vol. 27, 1926, pp. 1077-1078, 1421.

Class B

House shall be 12 by 18 feet, with long dimension parallel to the track; house shall have sliding door 8 feet in clear at extreme end of track side to permit the storing of handcar.

Class C

House shall be 10 by 14 feet, with the short dimension parallel to the track, with double swinging doors, swinging out on the end nearest the track.

Building shall be on wooden posts, unless the location can be permanent, in which case brick or concrete piers may be substituted.

[9]ROOFINGS

General

The following factors should be considered in selecting a roofing for a railway building:

(1) Probable life, including chance of damage by the elements and ordinary wear.
(2) Possibility of leaks due to character of construction.
(3) Initial cost.
(4) Cost of maintenance.
(5) Fire resisting value.
(6) Appearance, and architectural value.

The type of roofing to be used is in general controlled by the structural design of the building, its location and use, and conversely the design of the building should be adapted to the use of an efficient roofing.

An efficient roofing may be defined as a roofing which will insure the building against damage by rain or snow at the least annual cost consistent with the architectural effect desired. In special instances the value of the roofing as an insulator must be considered, and in all cases the fire resisting value should be given due weight.

Basic Materials

The basic roofing materials may be classified as follows:

(a) Slate, tile and asbestos.
(b) Metals.
(c) Bitumens used with felts and fabrics.
(d) Wood.

Slate.—When properly selected and applied, slate gives an ornamental roof of long life at a low cost for maintenance.

Slate should not be used on roofs having a pitch of less than 6 inches per foot, and should be laid with not less than a 3-inch headlap over the second course below. It is recommended that slaters' felt be provided under all slate roofing. In localities subject to heavy snow fall, snow guards should be provided on slate roofs.

Clay Tile.—Clay tile are made in a variety of shapes and sizes and may be obtained either glazed or unglazed. This type of roofing should be laid only on reasonably steep roofs and over a layer of waterproof felt.

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[9] Adopted, Vol. 12, Part 1, 1911, pp. 588, 623; Vol. 14, 1913, pp. 839, 1084; Vol. 15, 1914, pp. 705-709, 1099; Vol. 16, 1915, pp. 746, 1149; Vol. 27, 1926, pp. 1078-1082, 1421.

A clay tile roof is heavy and requires special roof framing. Skilled workmanship is needed to provide a watertight roof. The value of a clay tile roof lies chiefly in the architectural effect produced.

Roofs of clay tile laid on open strips are not recommended.

CEMENT TILE.—Tile made of Portland cement mortar produce ornamental and permanent roofs when properly manufactured and laid. Careless methods of manufacture may produce an unreliable product. The process of manufacture should be covered by a definite specification and subject to inspection.

Cement tile are manufactured in two forms, viz., shingle tile and structural tile.

(a) Shingle tile should be applied in the same manner as slate and under the same conditions.

(b) Large cement tile, reinforced with metal and laid without sheathing directly on purlins make a permanent and economical roof for large buildings.

Glass can be introduced into the tile, taking the place of skylights.

ASBESTOS SHINGLES.—Shingles made of Portland cement and asbestos fibre make an ornamental and durable roof covering. They should be applied in the same manner and under the same conditions as slate. These shingles are made in a variety of colors and patterns. The diagonal, or "French," method of laying these shingles is not recommended.

CORRUGATED ASBESTOS.—Corrugated asbestos sheets made of Portland cement and asbestos fibre make a good roofing material for some classes of buildings with steep roofs. The sheets are laid directly on purlins, or strips, without sheathing, and produce a practically permanent roof.

METAL ROOFING.—Sheet copper and lead are recognized as practically permanent roof coverings, but are not specially adapted for use on the average railway building on account of their high initial cost. Rolled sheets of pure zinc make a good roof covering at a lesser cost than copper or lead.

Iron sheets coated with tin make a good roofing material, but require periodic painting to give long life.

Galvanized iron or steel sheets have some merit for minor buildings, but should be considered only where first cost is a controlling factor.

Steel sheets coated with asphalt and asbestos fibre have considerable merit.

Small metallic shingles of copper, zinc, tin or galvanized iron or steel are not recommended for general use.

BITUMINOUS ROOFINGS.—Roofs built up of layers of felt cemented together with pitch or asphalt and with or without a mineral surface are especially valuable on flat surfaces. They may, by using special kinds of asphalts, be used on roof surfaces having a slope as steep as 6 or 8 inches per foot.

BITUMENS.—The common bituminous materials used are:

Coal tar pitch.
Asphalts (petroleum and natural).
Vegetable gums.

Their value lies in the fact that they are practically insoluble in water and that they are elastic, adhesive and comparatively stable.

Coal tar pitch is obtained from the destructive distillation of bituminous coal. It is easily affected by heat and cold, is not acted upon at all by water, is easily worked and if properly protected is very stable. It should ordinarily be used as it comes from the still, "straight run," of a consistency suitable to the climate and to proper application.

Roofing asphalts may be either natural lake asphalts fluxed with oils, or petroleum asphalts obtained from the distillation of crude oil.

The lake asphalts are unsuitable for roofing in their natural state.

A single asphalt fluxed with a single oil is for most purposes a crude and unsatisfactory material. To secure the best results for any desired purpose, several oil and asphaltic substances must ordinarily be compounded. This requires skill and experience. Those properly made are for certain conditions invaluable, particularly for ready roofing, for which tar products are not suited.

The asphalt and petroleum products are not so readily affected by heat and cold as is coal-tar pitch, and lesser amounts of them are necessary to get good results. They are more expensive, require more skill in handling, and when protected, some at least are to some extent liable to lose their life by drying out of the oil fluxes. Unprotected, they do much better than does coal-tar.

The petroleums found in this country vary considerably, and grade roughly in quality, according to location from East to West. The California oils, with their asphaltic base, furnish materials especially valuable for roofing.

Water gas-tar pitch, a by-product in the manufacture of water gas, which is enriched by gas from petroleum oils, resembles coal-tar. It is inferior to coal-tar for roofing purposes, and materials made from it should only be accepted in the low-priced products. It has more value as a saturant of felts than as a coating.

Of the vegetable gums, cotton seed gum makes a good material for built-up roofings. It is stable in water, oxidizes very slowly and is easily worked.

FELTS.—The bituminous substances are used with felts whose qualities considerably affect the roofing. The ordinary felt is made of rags, mainly cotton. "Wool felt" is a misnomer. Asbestos felts, as compared with the rag felt act less as a carrying medium for the bitumen, but rather as a protection to the layers of bitumen. They are not suited for use with coal-tar pitch, but are not injured by hot asphalts. They are more expensive than rag felts, but have some peculiar and valuable qualities.

Burlap made from jute decays easily when not protected. It is used in a few ready roofings with rag felts to increase their tensile strength, the need of which is not generally accepted.

BUILT-UP ROOFS.—The built-up roof is especially valuable for flat surfaces. It can be made as heavy as desired, and if properly laid and of good materials gives a roofing which by long experience has been shown to be economical and efficient.

For the flat roof built under average conditions, coal-tar pitch is recommended in preference to asphalt products. It is more easily handled, requires less skill, and, while more material is necessary, it is still cheaper, and in our opinion more certain results can usually be expected from its use when laid by the average contractor. The large amount of material, while heavy, has insulating value. Good results, however, can be expected from built-up roofs using good asphalt compounds, where laid by skilled workmen.

When the slope of the roof is over three inches to the foot, the application of a built-up roof becomes more difficult for both coal-tar and asphalt, it being harder to get even mopping, and there is more chance of accident for the men.

The desirable straight-run coal-tar pitch cannot be used, it being necessary to add some stiffening material which is supposed to somewhat affect the life of the pitch. This must not be done except under supervision skilled in such work, and especial care must also be taken in the selection and application of the stone or slag coating.

Built-up roofs with a ready roofing for the coating sheet are proposed by various manufacturers. They should have their best value for steep slopes.

The advantages of a coal-tar pitch built-up roofing are such that it is recommended that where a permanent roof is desired, and where the character of the structure allows, the building be so designed as to allow its use. A flat roof makes an economical structure and has small fire hazard. A pitch of from one-half to one inch to the foot is better than anything steeper.

PREPARED, OR READY ROOFING.—Prepared roofings in general consist of one or more layers of felts, cemented together at the factory and shipped in rolls. They may have a smooth surface, or be coated on the weather side with crushed mineral.

The ready roofing has better value for the steeper roofs than for those of small pitch. It averages much cheaper than the built-up types. Most kinds, to get a fair life, require occasional recoating. For flat slopes they are hard to lay absolutely tight, and they are not economical for a permanent structure, but on slopes of from three inches to the foot up, their use is more justifiable.

Ready, or prepared, roofings are recommended for use on small, temporary and other buildings, where the cost, considering maintenance of more expensive roofings, is not justified. They are also of value for steep slopes, where a built-up coal-tar cannot be used, and for locations where the skilled labor necessary for a built-up roof is not available. The steeper the slope the greater their relative value and the wider their economical field.

The heavier varieties are, in general, the more desirable because of their chance for longer life and their greater fire-resisting value. In making selections the reliability of the manufacturers, service tests and the cost should be governing factors.

ASPHALT SHINGLES.—Shingles, similar in composition to prepared roofing, with either plain or mineral coated surfaces, and laid shingle fashion on steep surfaces, are suitable for minor buildings of a more or less temporary character. Their use is not recommended on permanent buildings.

WOOD SHINGLES.—The use of wood shingles is not recommended for railway buildings on account of the fire hazard.

Workmanship

The success and life of any roof will depend as much on good workmanship as upon careful selection of materials. Thorough inspection of workmanship is recommended.

Flashings

The installation of adequate flashings should be given careful consideration in connection with all roof work. Most of the trouble in alleged defective roof work can generally be traced to insufficient or incorrect flashings. Flashings should be selected so as to have approximately the same life as the roofing materials.

Protection

Where a built-up roof is subject to wear, and where the character of the construction warrants the expense, flat tiles or brick should be used as a protective coating instead of gravel or slag.

Guarantee

The practice of depending entirely upon the guarantee in selecting roofings cannot be trusted to secure proper results, although the length of guarantee offered with a built-up roof is an indication of its probable life.

[10]FLOORS FOR RAILWAY BUILDINGS

Transfer Platforms

Wood plank platforms should be laid preferably with the planks parallel to the line of trucking traffic. Metal plates may be used for a runway to produce easier trucking and to reduce wear on the plank. Concrete floors are used in some cases and for extremely heavy traffic, a concrete base with creosoted wood or asphalt block or asphalt mastic wearing surface is used.

Freight Storage Houses

For freight storage houses, which are usually of fireproof construction, concrete floors are generally approved.

Freight Piers

Floors on freight piers must, of necessity, largely conform to the style of construction used in the pier. They should be fire-resisting and have flexibility enough to take up the vibration caused by boats being moved along the pier.

Blacksmith Shops

Floors of cinders, earth or clay are to be preferred in all cases.

Machine Shops

In small buildings a wood plank floor, of thickness suited to the severity of service, is common practice. For buildings of a higher grade, wood blocks (preferably treated), asphalt blocks or mastic give excellent results. Concrete floors may be used where local conditions justify this construction as economical, although their lack of resiliency may result in discomfort to employees and their hard surface may damage tools dropped upon it.

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[10] Adopted, Vol. 27, 1926, pp. 1084, 1421.

Paint Shops

In passenger car paint shops a concrete floor meets all requirements and it is doubtful if a more expensive type of floor is justified. In freight car shops, where paint is sprayed on, a floor of cinders is suitable.

Freight Car Repair Shops

Wood floors can be used if something better than cinders is desired and if provision has to be made for trucking material between tracks. Concrete is very satisfactory for a floor of higher grade.

Store Houses

Concrete floors are satisfactory and are in common use, but in locations where very heavy material is handled, wood blocks, asphalt block or mastic are to be preferred. In small storehouses, at outlying points, the ordinary wood plank floor is commonly used.

Oil Houses

Because of the necessity for fireproof construction, concrete is recommended for oil houses.

Carpenter Shops

In carpenter shops where considerable bench work is done, wood plank floors are desirable because of the comfort they afford to workmen. Concrete floors are more easily kept clean and are sometimes used.

Office Buildings

Office buildings of the better class should have oak, maple or dense pine floors as required by the use for which the various rooms are intended. Hallways and toilets should have floors of concrete, marble, tile (either natural or composition), terrazzo or some kind of a sanitary composition, provided the importance of the building warrants the expenditure. For office buildings of lesser importance, floors of composition, concrete or pine are satisfactory. If concrete is used it is desired to provide some kind of a resilient covering for added comfort to employees.

Passenger Stations

In large city stations and in suburban stations of importance terrazzo, tile or some other high grade type of composition floor is generally accepted as best meeting the requirements. In such locations the architectural suitability of a floor is of as much importance as its wearing qualities. For ramps, a non-slip wearing surface is essential. For small stations concrete or wood floors are commonly used. In stations where concrete or terrazzo floors are used, a wood or other type of resilient floor covering should be provided in the ticket office.

Signal Towers

Floors in signal towers may be of concrete, composition or wood, depending upon the type of construction of the building. When concrete is used in connection with electrical machinery, precaution should be taken to secure a non-dusting surface.

Freight Houses

In small houses, which are usually of frame construction, a plank floor laid on wooden joists is satisfactory and economical. In larger and more important houses, where much trucking is done, a floor of greater first cost is justified and appreciable economies in operation can be obtained by the selection of a suitable trucking surface. Concrete floors are fairly permanent, sanitary and easy to keep clean, but have as disadvantages a possible failure of the wearing surface, especially at expansion joints, and an unyielding surface which occasionally produces complaints from truckers. Expansion joints should be located outside of the heavily used area wherever practical. If a concrete surface is not considered suitable, some different type of wearing surface such as square edge maple, wood or asphalt blocks or asphalt mastic may be laid on the concrete. A creosoted wood plank floor on a concrete base with a wearing surface of untreated maple flooring has been known to give very satisfactory service. If the cost of a concrete base is not justified an excellent floor can be made by laying creosoted plank on a fill of cinders or gravel, the top layer of which is treated with tar or some asphaltic compound, and covering the creosoted plank with a maple wearing surface. Asphaltic concrete may be applied over a wood base with good results.

Engine Houses

In minor houses, where not many running repairs are made, a floor of clean engine cinders, well compacted, is frequently used, but whenever possible a better type floor should be provided. For houses of more importance concrete floors or floors of brick or creosoted wood blocks on concrete base should be used. Asphalt floors, either mastic or block, if used in engine houses, should be of such composition as to resist the action of steam and oil.

[11]PAINTS FOR RAILWAY BUILDINGS

Paints are applied to railway buildings:

(1) To protect the materials of which the building is constructed, thus prolonging its life.
(2) To improve the appearance of the building.
(3) To improve the lighting of the interior, resulting in increased efficiency of employees and a reduction in expenses for artificial lighting.
(4) To improve the sanitary conditions.

Properly selected paints will preserve wood, metal and other building materials and the repainting of the surfaces of such materials is desirable and necessary at certain intervals due to the perishable nature of paint, and the loss of its protective properties and deterioration in appearance.

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[11] Adopted, Vol. 27, 1926, pp. 1086, 1421.

For office and shop buildings, paints which diffuse the maximum amount of light will preserve the health and eyesight of workers, reduce accidents and increase the output per employee, and in addition produce a substantial saving in artificial lighting bills.

The use of correct paints for toilet rooms, offices and rooms for storage of food products improves their sanitary condition. Paints should be selected which can be cleaned without injury to the paint, and which will produce the most impervious surfaces.

Questions which arise in connection with painting buildings are:

(1) When does the structure need painting?
(2) What paints shall be used?
(3) How shall these paints be applied?

Answers to these questions follow:

(1) A structure requires painting when first erected, and thereafter when the paint shall have ceased to have a protective, lighting or sanitary value, or when it shall have lost the standard of appearance which is generally maintained.

(2) In general, most railways have adopted certain standards of distinctive colors for painting buildings, each company having its own combination of colors, which has been selected for various reasons, such as longevity, cost, personal taste of departmental heads, etc. Aside from prolonging the life of its structures, the railway which makes it a practice to keep its buildings painted with attractive, pleasing colors, gains an unconscious good-will from its present and prospective patrons, which, while difficult to express in terms of money, nevertheless has a decided value in advertising. An efficient paint should be considered, one which will have the maximum protective value, permanence of color, durability, covering capacity and hiding power.

The factors which produce an efficient paint are a selection of proper ingredients, and careful grinding and mixing of these ingredients. The final product of the process of painting is the paint coating on the structure, which should have the maximum strength, impermeability and durability, and paints which fulfill these conditions are made from formulas developed to produce a paint mixture which will have the minimum voids, and at the same time meet the requirements as to color.

The protective value of a paint is largely dependent on the ability of the paint film to prevent air and moisture from reaching the surface of the structural materials, and also, to some extent, on the preservative nature of the ingredients of the paint. Paints having the greatest protective value are those composed of a combination of pigments whose particles have varying characteristic sizes, bound together by a vehicle which has a high power of absorbing oxygen. Of such paint vehicles the most satisfactory is linseed oil, which when spread in the form of a thin film will take up oxygen and form a hard, elastic, non-sticky product called linoxyn. Although this organic linoxyn is perishable yet its purity, strength and protection from attack makes for the longevity of the paint. The inorganic or powdered mineral solids of the pigments will crumble unless held together by the linoxyn, and the pigments must be so ground and blended that they will protect the binder and present the greatest mineral surface to atmospheric attack. In other words, the strength and durability of a paint coating is dependent not only on the strength and durability of the pigment particles, which should consist of a properly proportioned blend of pigments of determinate sizes, in part at least chemically inert, but also on the requisite thickness of a paint film. The application of these principles results in the design of paint formulas to produce paint coatings neither too thick, and therefore uneconomical and subject to internal strain, nor too thin and thus weak and inefficient for protection.

The permanence of color of a paint will be dependent on the unfading qualities of the color producing pigments, while the hiding power will depend on the density of the pigments ground in oil and the thickness of the film.

In general there are two methods for specifying and ordering paints:

(a) To order the proper grade of product from a reputable manufacturer. There are manufacturers who produce and sell efficient paints. They have studied the subject exhaustively and are constantly trying, by improved methods, to increase the efficiency of their product.

Satisfactory results can be obtained by placing the requirements that the various classes of paints are to meet before reputable manufacturers and depending on their judgment and ability in producing the most efficient paints for the service expected. By keeping proper service records of paints there will be sufficient data to select the proper standard product of a number of manufacturers for the purpose required.

(b) To order in accordance with specifications or formulas prepared by the Railway Company.

In ordering paints under specifications or formulas, the paint formulas must be prepared and developed by experts in paint technology. The formulas should be revised from time to time so as to include improved manufacturing methods and newly discovered materials.

In preparing specifications for the purchase of paints, better results will generally be obtained by specifying rigid physical tests as a method of judging quality, rather than by giving definite formulas based on chemical composition.

Chemical analyses of paints will to a certain extent detect substitutions of improper materials, but may not show up imperfect methods of manufacture.

In the purchase of paint many substitutions may be made which will still come within the letter of the specifications and many processes of mixing and grinding can be used which, even with the best ingredients, will produce a poor paint.

(3) The service life of a paint is as much dependent upon its correct application as upon the composition of the paint itself.*

The most important factor in painting work is to see that the surface on which the paint is to be applied is properly prepared. Such surfaces should be clean and dry and free from conditions which might have a tendency to cause the paint to scale, blister or discolor.

Paints should be furnished preferably in cans, and for recoat work, mixed to the proper consistency for direct application. Under certain conditions paints will require some thinning, which should be done only with pure spirits of turpentine or linseed oil.

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*See Specifications for Railway Buildings—Painting and Glazing.

When applied, paints should be brushed out to smooth coatings of uniform thickness so as to get the maximum spreading capacity of the paint consistent with a film of the thickness to wear well and give the desired protection.

Where repainting is done in two-coat work, the first coat should be allowed to dry hard before any succeeding coat of paint is applied.

The failure of paint coatings before their expected life has been reached is a loss to the Railway Company, both from the partial loss in materials and labor used and from the deterioration of the structural materials in the building due to the lack of protection furnished.

A record of all painting work done on buildings should be kept on suitable forms, and the date painted or stenciled on buildings.

The following form shows the information that should be given and is recommended for use.

Recommended Form for Painting Records

Size of card, 5"x8"

BUILDING PAINTING

STRUCTURE DIVISION

DATE STARTED DATE COMPLETED CONDITION OF OLD PAINT

WHAT PORTION PAINTED

COST RECORD		NO. GALS OF PAINT	COLOR OF PAINT	MAKER OF PAINT	COST PER GALLON	COST & MISC MAT'IAL	TOTAL COST OF MATERIAL	COST PAINTER LABOR	COST OF ST'GI'G & CLE'NING	TOTAL COST
OUTSIDE 1ST COAT	BODY									
	CANOPY									
	WAINSCOTT									
AREA.	TRIM									
OUTSIDE 2ND COAT	BODY									
	CANOPY									
	WAINSCOTT									
AREA.	TRIM									
INSIDE 1ST COAT	BODY									
	CEILING									
	WAINSCOTT									
AREA.	TRIM									
INSIDE 2ND COAT	BODY									
	CEILING									
	WAINSCOTT									
AREA.	TRIM									
ROOF AREA	1ST COAT.									
	2ND COAT.									

TOTAL MATERIAL TOTAL LABOR TOTAL COST CORRECT

EXPLAIN ON BACK ANY REASON FOR EXCESSIVE COST & WEATHER CONDITIONS FOREMAN

SPECIFICATIONS FOR BUILDINGS FOR RAILWAY PURPOSES

Section 1

[12]GENERAL CONDITIONS

1. General

These general conditions are intended to be used in connection with the American Railway Engineering Association Construction Contract form as published in the Manual, and shall apply to all sections of these specifications with equal force.

2. Company, Engineer and Contractor Defined

As used in these specifications the term Company shall be understood to mean the Railroad or Railway Company, the term Engineer shall be understood to mean the Chief Engineer of the Company or his duly authorized representative, and the term Contractor shall be understood to mean the person, firm or corporation agreeing to perform the work covered by these specifications.

3. Drawings Furnished by the Company

The drawings furnished by the Company shall be considered as part of and illustrating these specifications. These specifications are intended to supplement the drawings, the two being considered co-operative. Drawings and specifications will be part of the contract and are equally binding. They are the property of the Company and shall be returned when work is completed.

The drawings show the general character of detail work, but the Company reserves the right to furnish proper scale details of such portion as may, in the judgment of the Engineer, require them. In preparing such details slight modifications may be made if necessary without in any way invalidating the contract. The Contractor shall not execute any work requiring such details until these have been furnished, and all work shall conform with these details when executed.

Figures on drawings shall take precedence over measurements by scale, detail drawings over small scale drawings, and full size details over all other drawings. The decision of the Engineer shall be final as to the interpretation of drawings and specifications.

4. Errors or Discrepancies

If the Contractor in course of the work finds any discrepancy between the plans and the physical conditions of the locality, or any errors in the plans, or in the points given for the construction of the work, it shall be his duty to immediately inform the Engineer in writing, and the Company will promptly verify and, if necessary, correct such errors. Any work performed before these discrepancies or errors have been corrected will be done at the Contractor's risk.

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[12] Adopted, Vol. 27, 1926, pp. 1092, 1422; Vol. 28, 1927, pp. 662, 1414.

5. Working Drawings

The Contractor shall submit to the Engineer in triplicate, copies of all working drawings and erection diagrams of all parts of the work, including both structure and equipment.

Said drawings shall include list of all parts of equipment with pattern numbers or other necessary designation in order that repair parts may be readily ordered in the future.

These drawings shall measure .... outside and .... inside, ... border lines. All such drawings must be approved by the Engineer before the work involved is started. The approval of said working drawings by the Engineer shall not imply any change in the specifications or relieve the Contractor from the responsibility of any errors thereon. No change shall be made on any approved drawing without the written consent of the Engineer. The Contractor shall supply additional copies of working drawings and erection diagrams on request.

Upon completion of the work the Contractor shall furnish a complete set of corrected ink tracings on cloth, or VanDyke prints on cloth made from ink tracings, of all working drawings and erection diagrams and this set shall be a true record of the work as constructed.

6. Laying Out Work

Necessary lines, corners and elevations will be established on the site of the building by the Engineer. The Contractor shall erect permanent batter boards and protect the points so established until the work is completed and accepted. Using the points established by the Engineer, the Contractor shall lay out his own work and be responsible for its accuracy.

7. Prosecution of the Work

When the work of a Sub-Contractor engages with the work of any other Sub-Contractor, he must co-operate with the other Sub-Contractor and exercise extraordinary care to prevent injury to any work or material. Each Sub-Contractor shall do all necessary cutting, fitting and patching of his work where it engages the work of another Contractor or the Company.

8. Materials

All materials shall be new and of the grade specified, and shall be the best of their respective kinds for the uses intended.

PRICED MATERIALS.—Where the quality or kind of material cannot be definitely specified, the amount of money the Contractor is to pay for same is given in these specifications. The sum so given is intended to cover the purchase price of the materials and freight charges, but this sum shall not include any cost of hauling, cartage, supervision, preparatory work, profit, or the cost of erection; it being intended that the Contractor shall include such foregoing items in his contract price. The Engineer will select such materials and notify the Contractor of his selection and the price agreed upon, but the Contractor shall contract for the material and supervise its delivery and erection as fully as other parts of the work.

If the required payment for such priced material should be more than the sum herein specified, the difference is to be paid by the Company, and if it should be less, the difference is to be deducted from the sum to be paid the Contractor under the contract.

"APPROVED" MATERIALS.—The term "approved" in this specification signifies that the Engineer must be consulted as to the source from which the material is to be purchased as well as its general quality and construction, but such approval does not mean the acceptance of the material actually furnished if it should be defective.

SPECIAL MATERIALS.—Special brands of materials or devices mentioned in these specifications or shown on the drawings are named for the purpose of establishing a standard or criterion of quality and character desired. Other materials of equal quality and adaptability to the purpose for which they are intended may be substituted, but only with the written approval of the Engineer. If the Contractor desires to substitute some other brand of material for that called for, he must submit a statement with his proposal, clearly and fully describing such substitutions as he desires to make. Where a specific make or kind of apparatus is called for and furnished by the Contractor, the furnishings of such apparatus does not relieve the Contractor of liability until he shall make such apparatus or appliance operative so that it will successfully perform the function for which it is intended. The Contractor shall protect the Company against claims on account of patented devices or parts proposed by him.

9. Equipment

The Contractor shall provide all equipment required for the execution and completion of the work, including all staging, scaffolding, apparatus, tools, etc., which are necessary. All equipment must meet with the approval of the Company and the Engineer may require the removal of any portion of equipment which is defective or unsuitable for the proper prosecution of the work and the Contractor will be required to substitute therefor satisfactory equipment without delay.

10. Permits, Laws and Ordinances

All work shall conform with the State or Municipal laws, ordinances or regulations governing such work. The Contractor shall give all requisite notices in connection with his work to the proper authorities, and shall procure at his own expense all permits, licenses, etc., of every description, necessary for the construction and completion of the work, and shall deliver to the Company all certificates of inspection for plumbing, electric wiring, or any other branch of the work for which such certificates may be required in connection with this contract.

Whenever these specifications, or any document which they supplement, conflict with the building code of the city or town in which the work is executed, the Contractor shall submit the question as to which to follow to the Engineer and abide by his decision.

11. Temporary Toilet Facilities

The Contractor shall establish and maintain, in a location approved by the Engineer, temporary toilet facilities for the accommodation of his employees.

12. Temporary Office

The Contractor shall provide in a suitable location on the site, for the exclusive use of the Engineer, a temporary office, which shall be weatherproof and have a door and window.

13. Temporary Heat

Where temporary heat or heat during the construction of the building is required for drying plaster or paint, for the prevention of damage to materials by freezing, or for any other reason, such heat shall be provided by the Contractor at his own expense unless otherwise specified hereinafter.

14. Force Account Work

Whenever any work is done or material furnished on a force account basis, that is, for a price based upon the actual cost of labor and materials plus an added percentage to cover overhead expenses, superintendence, profit, use of tools and equipment, and Contractor's risk and liability, the actual cost shall not exceed the fair market value of the labor and material furnished. Where work is done on this basis the time of all employees shall be entered by the Contractor on forms supplied him for that purpose, and checked and signed in duplicate daily by the Contractor and the Engineer, and no labor not so entered and checked will be allowed.

15. Accounting Requirements

At the completion of the work, the Contractor shall furnish a complete list of all quantities in accordance with the Company's classification for all work underground for each item or structure, and shall furnish in lump sum form, the cost of the superstructure for each item or building, this cost to include the proportionate part of the Contractor's overhead and profit.

Where the work is of such nature that existing facilities are removed or remodeled by the Contractor he shall furnish the Company with a statement showing in detail the cost of such work, the materials removed and the disposition of the materials. The above information shall be furnished in order to comply with Interstate Commerce Commission accounting requirements.

Section 2

[13]EXCAVATING, FILLING AND BACKFILLING

1. General

The Contractor shall furnish all labor, material, tools and equipment except as otherwise noted, necessary to entirely complete all excavations for foundation walls, piers, footings, pits, ducts, tunnels, basements and any other excavation which may be implied or shown on the drawings to receive the subsequent work.

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[13] Adopted, Vol. 27, 1926, pp. 1095, 1421.

Any excavation paid for or deducted on a unit price basis shall be for the actual measured yardage.

No allowance shall be made on account of slope to the sides of excavation, but measurements for quantities of excavation shall be taken to outside of sheeting.

The unit price paid or deducted shall include the whole value of the sheeting, bracing or any other material actually used in connection with the work, either as a form for concrete foundations, as a protection against caving during the process of excavating, or as a cofferdam, and shall also include any pumping or bailing which may be necessary.

2. Classification

All material excavated shall be classified as rock excavation, wet excavation and common excavation.

3. Rock Excavation

Rock excavation shall comprise rock in solid beds or masses in its original position, which in the judgment of the Engineer may best be removed by blasting, and detached rock or boulders measuring one cubic yard or more.

4. Wet Excavation

Wet excavation shall comprise that material, not included under rock excavation, which requires pumping or sheet piling to overcome seepage and overflow.

5. Common Excavation

Common excavation shall include all materials that do not come under the classifications of rock or wet excavation.

6. Soil Test

Before any foundation work is placed, the Contractor shall satisfy himself that the soil encountered is of such a nature that it will support the structure as designed; in case of doubt he must notify the Engineer and no foundations shall be laid until a proper investigation is made.

7. Beds for Footings

The beds for footings shall be leveled and free of all loose material before any foundations are put in place. No footings shall rest on filled ground except where absolutely necessary, and all filling under such footings shall be sand or other approved filling, puddled and tamped in place. No such footings shall be put in place by the Contractor without first obtaining permission from the Engineer.

8. Quicksand Pockets

If any quickstand pockets or other soft spots are encountered beneath foundation walls, piers or footings, the same shall be excavated and filled with concrete, the extra work being paid for on the basis of unit prices provided in contract.

9. Pumping and Bailing

The Contractor shall perform all pumping and bailing necessary to keep all excavation entirely free from water during the progress of the work under all circumstances and contingencies which may arise, using such means as may be best adapted to conditions. The cost of pumping and bailing shall be included in the Contractor's bid for excavation.

10. Blasting

The Contractor shall do all blasting necessary in connection with the excavation as shown on the drawings. All drilling, placing of charges and shooting together with the covering of blasts, shall be done in an approved manner. All work in connection with blasting shall be done in strict accordance with any laws or ordinance in effect where the work is located.

11. Disposal of Excavated Material

Excavated material shall be used for backfilling around all underground work. After forms for such work have been removed and the work has been inspected by the Engineer, the Contractor shall fill up to the finished grade as shown on the drawings.

Only material suitable for backfilling shall be so used. Large frozen lumps, boulders, etc., shall not be used. Backfilling must be placed in layers not to exceed six inches, each layer being thoroughly tamped and puddled.

The Contractor, when so required, shall haul and place surplus excavated material within a distance not to exceed 300 ft. from the building as directed by the Engineer.

Any surplus excavated material which cannot be disposed of within 300 ft. of the building shall be disposed of by the Contractor, unless otherwise released by the Company.

12. Filling

Sand or cinder filling where called for on the drawings, shall be thoroughly tamped, rolled and compacted in place by the Contractor. Where floors are on fill, the fill shall be placed in layers and thoroughly puddled, tamped and rolled or flooded. Wherever such fill occurs it shall be included in the lump sum price for the structure in which it occurs. Sand fill shall be clean sand free from sticks or other foreign matter. When cinder fill is used, cinders will be furnished by the Company, in cars as near as practicable to the site of the work, but must be unloaded and placed by the Contractor.

No filling or backfilling shall be done at a time when there is danger of frost entering the material, except at the discretion of the Engineer.

13. Grading and Final Cleaning

All grading that may be necessary around the buildings as shown by the drawings shall be done by the Contractor. Cinders, sand or clean dirt shall be used for the work as called for by the drawings.

At the completion of the work the Contractor shall thoroughly clean up and remove any rubbish, dirt or excavated material from site as called for under disposal of excavated material, and leave the site clean and graded to finish grades as shown by the drawings.

14. Pile Foundations

Where timber foundation piles are required or shown on the drawings these shall be furnished and driven by the Contractor, unless otherwise provided for in the Contract. Contractors shall quote in their bids a unit price per linear foot penetration below cut-off, for furnishing, driving and cutting of piles.

Timber piles shall be furnished in accordance with the American Railway Engineering Association specifications covering piles for trestles, except that where piles are to be untreated they shall not be peeled. Piles that will be cut off below permanent moisture will not be treated. Piles which will extend above the line of permanent moisture shall be treated with creosote oil, full cell process, in accordance with the A.R.E.A. Specification for Treated Timber Piles. Pile shall be driven by a steam or drop hammer to refusal, or until the penetration per blow under the last blows of a 2000-lb. hammer, falling 20 feet, does not exceed one inch. They shall be driven in location shown on the drawings without variation of more than one foot in any direction. The Contractor shall excavate around and cut off the piles at the elevations shown and properly prepare the piles to receive the masonry or other parts of the structure. Piles shall be cut off in a horizontal plane unless otherwise shown on the drawings. Where the contract provides that the piles shall be furnished and driven by the Railway Company, the Contractor shall provide in his bid for excavating around and cutting off the piles as described above.

The lengths of piles necessary shall be fixed by the Engineer after test piles have been driven. The cost of driving test piles will be paid for by the Railway Company.

15. Underground and Overhead Structures

All gas, water and drainage pipes, sewers or conduits, shall be supported in place by the Contractor and all expense attending their renewal shall be borne by him. All telegraph, electric light or telephone wires, signals, etc., which in the judgment of the Engineer interfere with the progress of the work shall be removed without expense to the Contractor. During construction the Contractor shall maintain in safety, permanent poles, wires, sewers, pipes or conduits affecting his work or with which it may interfere. If damaged through his negligence, all expenses attending repairs thereto shall be borne by him.

16. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work shall be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of these specifications shall be considered to apply with equal force to this section of the specification.

Section 3

SEWERS AND DRAINAGE[14]

1. General

The Contractor shall furnish all materials and labor required to make the excavation and construct the sewers, manholes, catchbasins, sewer connections to existing manholes, etc., as called for on the drawings.

2. Excavation

All excavation shall be done in accordance with the section of these specifications covering excavation. In general the excavation shall be to line and grade as furnished by the Engineer, and shall be made by open cut from the surface and the clear width at the bottom of trench shall be at least one foot greater than the diameter of the pipe. The sides shall be cut vertically or with only slight inclination. When the material encountered permits, the bottom of the trench shall be rounded and a hole dug under each joint to give the pipe an even bearing and permit the making of the joint. Where the trench is excavated below grade, except at joints, it shall be refilled to grade with easily compacted material and thoroughly tamped. Bids shall be based on common excavation. If rock or wet excavation is encountered the Contractor shall receive compensation for the excavation according to his unit price per cubic yard submitted for rock or wet excavation less the amount of his price per cubic yard submitted for common excavation.

3. Pumping and Bailing

The Contractor shall pump, bail or otherwise remove all water that may be found or that may collect in the trenches while the sewer is being laid. No manholes, catchbasins or sewers shall be constructed or laid in water, nor shall water be allowed to run through the sewer until the mortar has satisfactorily hardened. All necessary precautions shall be taken to prevent the entrance of sand, mud or other obstructing material into the sewer. Any such material remaining in the sewer when completed, shall be removed by the Contractor.

4. Sheeting

The Contractor shall furnish, place and maintain such sheeting and bracing as may be required to support the sides of the excavation and insure the protection of the work. The sheeting and bracing shall be removed as the work progresses, in such manner as to prevent the caving in of the sides of the excavation or injury of the sewer.

5. Grade, Joints, Etc.

Each pipe shall be laid on a firm bed and in perfect conformity with line and grades as given by the Engineer.

The end of each pipe shall be pressed firmly into the bell of the other in such manner that there shall be no shoulder or want of uniformity of surface on the interior of the sewer. The joints are to be as uniform as possible in thickness and thoroughly filled with cement mortar. Each joint is to be wiped clean on the inside as the work progresses. After the joint is made the pipe shall be firmly fixed in place by means of earth carefully placed around same before the following pipe is laid.

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[14] Adopted, Vol. 27, 1926, pp. 1098, 1421.

6. Backfilling

No portion of a trench or excavation shall be backfilled until the sewer contained in it has been examined and approved.

No rock or frozen earth shall be put in the trench until the refilling has reached at least two feet above the top of the pipe. Fine earth shall be carefully thrown into the trench and around the pipe in layers not more than six inches thick, each layer being thoroughly tamped. The remainder of the filling may be flooded or otherwise thoroughly compacted so that there will be no settlement. Any surplus dirt shall be disposed of as directed by the Engineer. Whenever the Engineer deems the excavated material unsuitable he may require the Contractor to furnish suitable material to be paid for at the price bid for per cubic yard for extra fill. Rock in pieces weighing over 50 lb. shall not be put in the trench. Any rock used as back filling shall be placed with alternate layers of earth so that all spaces between the pieces of rock shall be filled with earth.

7. Vitrified Sewer Pipe

The pipes and specials shall be of standard length and of the best quality of salt glazed vitrified double strength sewer pipe of the "Hub and Spigot Pattern." The pipe shall be smooth, dense and sound, thoroughly burned, impervious to moisture, free from laminations, cracks, flaws, blisters or other imperfections. The interior surface shall be smooth and well glazed and straight pipe shall be true cylinder and the interior diameter shall be the full specified dimension, the inner and outer surfaces shall be concentric. No pipe less than six inches shall be used except for downspout connections, or unless otherwise shown on the plans.

The pipe shall be subject to inspection and approval or rejection by the Engineer.

8. Mortar

Motar for cementing the pipe joints shall be neat Portland cement or a mixture of equal parts of Portland cement and sand, as directed by the Engineer, with only enough water added to give it the proper consistency. Mortar shall be mixed only as needed for use. The retempering of mortar that has become partly set will not be permitted.

Mortar for brickwork shall consist of Portland cement thoroughly mixed with sand, in the proportion by volume of one part loose cement and three parts sand.

9. Cement, Sand, Stone

Cement, sand and stone shall be of the quality as specified in the specifications for Concrete work, Section 4.

10. Brick

The brick used shall be of the best quality, sound and hard burned, uniform and free from lime and cracks and shall not absorb more than fifteen per cent in weight after being thoroughly dried, when immersed in water for twenty-four (24) hours, and samples must be approved by the Engineer.

11. Manholes and Catchbasins

Manholes and catchbasins shall be built at the places shown on the plans or as otherwise directed by the Engineer and shall be of the form and dimensions shown on the detailed drawings.

12. Cast Iron Covers

All covers shall be of tough gray iron, free from defets which would tend to weaken them, such as cold shuts, or blow holes, and shall be absolutely clean and have a workmanlike finish. They shall conform to the standards as shown on the plans.

13. Cast Iron and Reinforced Concrete Pipe

Cast iron pipes and special castings shall be used where shown on the plans or as directed by the Engineer. They shall be the bell and spigot type manufactured in accordance with the "Standard Specifications for Cast Iron Pipe and Special Castings" of the American Water Works Association for Class "A" pipe. The joints between cast iron pipe and special castings shall be made in the usual manner. Reinforced concrete pipe of a design acceptable to the Engineer, shall be used if called for by the plans. Joints shall be made as specified for Vitrified Pipe.

14. Foundation Drains

When the ground is wet or of a swampy nature, drain or farm tile not less than four inches in diameter shall be placed along all foundations on a very slight grade at approximately the level of the footings. These drains shall be placed in a layer of clean coarse gravel or broken stone not less than one foot thick, and shall be connected with the main drainage system.

15. Special Fittings

In case vitrified sewer is to be paid for on a unit price basis all "Specials" including Y's, tees, bends, etc., will be figured as two lengths of straight pipe.

16. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 4

[15]CONCRETE

(In preparation.)

Section 5

[16]BRICKWORK

1 General

The Contractor shall furnish all labor, materials, tools, scaffolding and equipment, except as otherwise noted, necessary to entirely complete any or all clsses of brickwork herein specified, according to the class of building and as shown or implied on the accompanying drawings, including all backing, covering of iron and steel, all piers, walls, chimneys and other special work shown, specified, or otherwise implied.

2. Classification of Brickwork

Brickwork shall be classified as either common brickwork or face brickwork. The class of brickwork to be used shall be determined by the class of the building or by notations on the accompanying drawings. Unless otherwise specified common brickwork shall be used on all buildings of mechanical terminals, shops, storehouses, isolated freight houses and similar buildings. In general, face brick shall be used for Passenger Stations and Auxiliary Buildings, Combination Passenger and Freight Stations and Freight Houses built in conjunction with Passenger Stations.

3. Common Brickwork

All common brickwork shall be laid even and true to line, plumb, level and with all joints accurately kept. All brickwork shall be laid with joints not more than 3/8 inch thick and bonded together with full headers every sixth course. All brick shall be good, hard, well burned brick free from cracks and uniform in size, shape and quality and shall not absorb more than ten per cent of their weight in water. They shall be laid in a full bed of mortar with shaved joints, neatly struck on all exposed walls. The bricks used on the face of the wall shall be selected whole bricks of a uniform size and with true, rectangular face.

Porous or salmon brick shall be thoroughly wetted either by immersion or sprinkling before being laid, except in freezing weather.

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[15] In preparation.

[16] Adopted, Vol. 27, 1926, pp. 1109, 1421; Vol. 30, 1929, pp. 551, 1470.

4. Face Brickwork

The exterior face brickwork shall be laid up with a selected and approved pressed face brick. The Contractor as a basis for his proposal shall figure on a face brick to cost $........... per thousand, f.o.b. building site or Company's lines as provided in the Letter of Invitation, and any variation from this price more or less will be adjusted according to the actual cost of the brick. Face brickwork shall be laid with all stretchers unless otherwise shown and shall be bonded either by blind headers or an approved metal wall tie every sixth course.

All pressed brickwork shall be laid true to line, plumb, level and with all joints accurately kept. All work shall be laid so that four courses shall not exceed 11 inches in height, and joints shall be raked out to a depth of at least ⅜ inch unless otherwise shown on drawings or ordered by Engineer. Where rough face brick is used, instead of raking the horizontal joints, strips shall be placed in those joints as the brick is laid up and after the mortar has hardened properly these strips shall be removed. The vertical joints shall be raked in the usual manner.

The Company reserves the right to deviate from the type of joint specified above so as to conform with the type of brick selected. All brick courses shall be so proportioned that they will work out evenly with height of windows and doors. No split or fractional courses will be permitted. All backing up of pressed face brick shall be as specified under common brickwork.

Porous or salmon brick shall be thoroughly wetted either by immersion or sprinkling before being laid, except in freezing weather.

5. Detail of Brickwork

All brickwork details such as lintels, belt courses and other trim shall be laid up according to details shown on accompanying drawings and as specified under either common brickwork or face brickwork.

6, Samples

The Contractor will furnish samples of all brick to be used, together with prices for the various kinds of face brick submitted for approval of the Engineer. The Engineer also shall have the option of obtaining samples and prices for face brick. The samples selected and approved will be filed with the Engineer and taken as a standard of material to be furnished and all material used in the work must be equal in all respects to the approved samples.

7. Cement

The cement shall meet the requirements of the American Railway Engineering Association's Specifications for Portland Cement. Cement that has hardened or partially set shall not be used.

8. Sand

Sand for all classes of brickwork shall be clean, sharp, coarse and of grains varying in size. It shall be free from sticks or other foreign matter, but it may contain clay or loam not to exceed 2 per cent.

Where so required for pressed face brickwork sand shall be clean, sharp, white sand of the very best quality.

9. Lime

All lime used shall be of good quality, in large lumps, free from cinders, or clinkers, must contain less than 10 per cent impurities and must slake readily in water, making a very soft paste, free from core. Before being used all lime shall be thoroughly slaked with water. No air slaked lime shall be used. The use of hydrated lime of an approved brand will be permitted at the discretion of the Engineer.

10. Mortar Color

A mortar color of an approved brand shall be used to color mortar for face brickwork, color and mixture shall be as approved by the Engineer. The Contractor shall upon request of the Engineer lay up samples of face brickwork with different shades of mortar in order that the Engineer may decide by comparison the proper shade of mortar to use. These samples shall be of a size not to exceed six square feet in area, and the Contractor shall build, if requested, not to exceed six such samples. In general, unless otherwise specified, or ordered by the Engineer, the mortar shall be colored slightly darker than the face brick used.

11. Mortar

Mortar for all common brickwork except where otherwise specified shall be composed of one part Portland cement and four parts sand thoroughly mixed and tempered with lime paste to make it work smoothly. Where directed, the mortar is to be as above specified, omitting the lime paste.

Mortar for all pressed brickwork shall be of either of the following mixtures, as directed by the Engineer. Uncolored mortar shall consist of one part Portland cement, one part lime putty and two parts sand, the sand and cement being mixed dry, then wet to proper consistency and lime putty added. If pressed face brick is to be laid with colored mortar, it shall consist of one part Portland cement to two parts sand with lime paste added to make it work smoothly and colored with approved mortar color as directed by Engineer. No more mortar containing cement shall be mixed at any one time than can be used within thirty minutes after mixing. Retempering cement mortar which has begun to set will not be permitted. No mortar which has frozen shall be used on the work.

In lieu of cement mortar, the Contractor may use, when permitted by the Engineer, a patented cement or a natural cement of a brand acceptable to the Engineer, in which case one part of the patented cement shall be used with two and one-half to three parts of sand. Such mortar shall be mixed and used strictly in accordance with the manufacturer's instructions and these specifications. No more mortar than is required for the current day's work shall be mixed.

12. Water Supply

The water shall be clean, reasonably clear, and free from oil, acid and injurious amounts of vegetable matter, alkalies or other salts. The Contractor shall arrange for his own water supply and shall pay for same.

13. Wood Centerings

The Contractor shall provide wood centers for all openings wherever necessary. Centers shall be strongly constructed, made to fit accurately to the work, be well supported and rigidly braced so as to carry all loads until the brickwork has set. At the completion of the work all centering shall be removed from the premises.

14. Scaffolding, Protection, Etc.

The Contractor shall provide all scaffolding, staging, ladders, etc., necessary for the work. All walls or other parts shall be securely braced and protected against damage by wind and storm during construction.

15. Anchors, Steel, Etc.

The Contractor shall provide chases for all pipes, set bearing plates for beams, etc., and build into the brickwork all anchors, bolts, ties, nailing blocks, etc., as indicated on drawings and will be responsible for accurate location of same.

16. Backing

Where so shown iron, steel and other material shall be backed up with brickwork in a manner indicated on details.

17. Flue Linings

Brick chimneys or flues which are not of such dimensions that fire brick lining is required or called for on detailed plans, shall be provided with a terra cotta flue lining from a point two feet below the lowest smoke pipe entering same to base of chimney cap. All joints in this lining must be completely filled with cement mortar and carefully pointed up. No lime mortar shall be used in laying up tile linings or brick flues.

18. Fire Brick Linings

Brick linings for circular concrete stacks shall be laid up with radial fire brick in cement mortar. The interior surface shall be true, plumb, perfectly smooth and without taper, with bed joints not more than ⅛ inch thick. This lining shall be entirely independent and separate from the stack proper.

19. Vitrified Tile Wall

Vitrified tile wall coping shall be provided where indicated on the accompanying drawings. It shall be best hard burned, salt glazed tile, laid in full bed of mortar of one part cement to three parts sand, omitting all lime.

20. Cast Concrete Coping

All walls where so indicated on the drawings shall be coped with cast concrete coping. This to be of the section as detailed and made in lengths of approximately six feet.

21. Cast Concrete Sills, Lintels, Etc.

Where so indicated on drawings, window and door sills, lintels, chimney caps, etc., shall be of cast concrete according to details shown for them.

22. Requirements for Cast Concrete

Concrete for cast copings, lintels, sills, caps, etc., shall be composed of one part Portland cement, two parts sand and three parts crushed stone or gravel of a size to pass a 1¼ inch ring. Exposed surfaces shall be troweled smooth and edges shall be smooth and unbroken. Cast concrete copings, sills, lintels, caps, etc., shall be set true, level and plumb and carefully pointed out. No cast concrete member shall be set until the concrete is sufficiently hard to prevent damage. Copings, sills and caps shall be provided with drips.

23. New Masonry Joining to Old

The Contractor shall use special precaution where new masonry work joints up with old masonry work, to see that the old work is sufficiently roughed up, anchors provided and work keyed so that an absolutely tight and neat bond is assured between old and new work.

The Contractor shall do all work in connection with cutting out old brickwork, stone work or concrete where required. Care shall be exercised to see that only such portion of the masonry is disturbed as is necessary.

24. Protection and Pointing Up

The Contractor must keep his work covered and protected from the action of the weather or frost. He shall also protect by boxing all dressed or ornamental work liable to damage. At the completion of the work or at any time when so ordered he shall do all patching in a most satisfactory manner, clean down and point up all brick work, etc., removing all surplus mortar and stains. All window and door frames shall be carefully caulked with oakum and pointed up after they have been inspected and before the staff bead is applied.

25. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed, and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 6

[17]STONE MASONRY AND CUT STONE WORK

1. General

The Contractor shall furnish all labor, materials, tools, scaffolding and equipment, except as otherwise noted, necessary to entirely complete any or all classes of stone masonry and cut stone work herein specified, according to the class of building and as shown on the drawings.

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[17] Adopted, Vol. 27, 1926, pp. 1113, 1421; Vol. 30, 1929, pp. 551, 1470.

2. Description of Stone

All stone specified or shown on drawings shall be sound, durable, well seasoned, from quarries approved by the Engineer and each stone shall be laid on its natural bed. When required by the Engineer samples shall be furnished, which shall be about 4 inches by 7 inches by one inch thick produced so that the large faces shall show the grain or rift of the stone, the finish specified shall be indicated on the large faces and at least two of the edges shall be rock face. Similar samples shall be provided when select stock is required for certain positions in the building. Samples submitted are to be typical of the extremes which the Contractor proposes to furnish.

3. Cutting and Setting Drawings

The Cut-Stone Contractor shall prepare and submit to the Engineer for his approval, when required, complete cutting and setting drawings (in triplicate) for all the cut-stone work in this contract. Such drawings shall show in detail sizes and dimensions of stones, the arrangements of joints and bondings, anchoring and other necessary details.

4. Carving

All carving shall be done by skilled carvers from approved models.

5. Cutting and Finish

All exposed faces shall be cut true. The stone shall be cut full to the square with joints as required. The arrises shall be full and true. Beds, ends and tops shall be dressed straight and at right angles to the face unless otherwise shown. No patching or hiding of defects will be permitted and lewis holes shall not be cut on exposed surfaces.

Washes shall be as steep as practical and drips of sufficient depth to shed water shall be provided on all projecting stones and courses.

Specially graded stone acceptable as to hardness, and color, as per samples to be submitted shall be employed for grade course steps and all other positions exposed to direct wear. Steps shall be cut with a slight pitch to the front.

The finish on exposed surfaces, except rock face work, shall be hand tooled work not less than 10 cuts to the inch.

Where molded work is tooled, the tooling shall run in the direction of the molding and not across.

Rock face work shall have no projection exceeding two inches. Edges shall be pitched to a straight line.

6. Lewis Holes

Lewis holes shall be cut in all stones weighing more than 300 lb. No lewis or other holes shall come within 2½ inches of the exposed face of the stone, unless the stone is less than 5 inches thick.

7. Mortar

Mortar for all stone work, except where otherwise specified, shall be composed of one part Portland cement, one part lime putty and two parts sand, the sand and cement to be mixed dry, then wet to proper consistency, and the lime putty added. If stone work is to be laid with colored mortar the following mixture shall be used: One part Portland cement, two parts sand, with lime paste added to make it work smoothly and colored with approved mortar color. No more mortar containing cement shall be mixed at any one time than can be used within thirty minutes after mixing. Retempering cement mortar which has begun to set will not be permitted. No mortar which has frozen shall be used on the work.

The cement shall meet the requirements of the American Railway Engineering Association's Specifications for Portland Cement. Cement that has hardened or partially set shall not be used.

Sand shall be clean, sharp, coarse and of grains varying in size. It shall be free from sticks or other foreign matter, but it may contain clay or loam not to exceed two per cent. Where so required for pointing face work, sand shall be clean, sharp, white sand of the very best quality.

Lime used shall be of good quality, in large lumps, free from cinders, or clinkers, must contain less than ten per cent impurities and must slake readily in water, making a very soft paste, free from core. Before being used all lime shall be thoroughly slaked with water. No air-slaked lime shall be used. The use of hydrated lime of approved brand will be permitted at the discretion of the Engineer.

8. Anchors and Dowels

Proper provision shall be made for anchoring and doweling the stone. Anchors and dowels shall be of the proper size and shape and thoroughly galvanized, or coated with asphaltum paint.

9. Setting

All stone shall be thoroughly cleaned on all joints before setting. Mortar shall be kept ¾ inch from the face of the stone to allow for pointing. Splashing exposed faces of stone with mortar shall be avoided. All beds and vertical joints shall be of a maximum width of ¼ inch unless otherwise indicated. The stone shall be set accurately, true to line and level by competent stone setters. Face stones shall be set on thoroughly wetted wooden wedges which are not to be removed until the building is cleaned and pointed. The ends only of all sills shall be set in a full bed of mortar, balance of sills shall be left free until pointed.

10. Broken Coursed Ashlar

The face stones shall be rock faced edges pitched to a straight line, and shall have parallel beds and rectangular joints.

The beds and joints for 6 inches back from face shall be dressed to lay not over ¼ inch joint.

The stones need not be laid up in a regular course, but shall be laid level on their natural beds, and shall be well-bonded, having at least one header, extending entirely through the wall, for every ten square feet of face surface. Headers shall be placed so that they come half way between the header of the course above and below. No stone shall be less than 6 inches thick, and no stone shall measure in its least horizontal dimensions less than 9 inches.

11. Boulder Masonry

Where shown on the drawings, foundation walls shall be composed of stone of proper size and thickness. They shall be of fair shape, and spalled so that they will lay with good even bearings on the wall. All stones shall be laid in full beds of mortar, all interstices filled and all exposed faces neatly pointed. All work must be thoroughly done and well bonded. A header, extending entirely through the wall, shall be built in every 8 square feet of surface. Each header shall break joint with the headers in the courses above and below.

12. Protection

Wherever necessary, all projecting individual stones or courses shall be protected against injury during the setting process by wooden covering, which shall be maintained in good and substantial condition until removed for the purpose of cleaning down the stone work.

13. Cleaning and Pointing

The face of the stone work under this contract shall be thoroughly cleaned upon completion, such cleaning to be done with soap powder boiled in clean water and applied vigorously with stiff fibre brushes. If necessary, clean, sharp, fine white sand may be added to the soap and water mixture. The use of acids will not be permitted for cleaning the stone work.

All face joints shall be brushed out ¾ inch in depth and pointed flush with mortar consisting of one part stainless cement, two parts clean white sand and sufficient cold lime putty to make as stiff a mixture as can be worked.

14. General Conditions

All material entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 7

[15]CLAY HOLLOW TILE

1. General

The Contractor shall furnish all labor, materials, tools, scaffolding and equipment except as otherwise noted, necessary to entirely complete any or all classes of clay hollow tile work herein specified, according to the class of building, and as shown or implied on the drawings.

The Contractor shall provide and erect all hollow tile exterior and interior bearing walls of hard burned hollow tile, true and regular in size.

Tile to which plastering is to be applied shall have all faces scored with special dove tail scoring to furnish a good bond.

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[15] Adopted, Vol. 27, 1926, pp. 1116, 1421.

All sub-dividing, non-bearing partitions, where shown on plans, shall be of hollow partition tile.

2. Hollow Tile Material

All hollow building tile shall be straight, uniform, free from objectionable cracks and burned to such a degree of hardness that it will pass the following requirements:

(a) **Standard Loadbearing Tile** shall have an absorption not to exceed 12 per cent and be capable of sustaining a load of at least 700 lb. per square inch of gross area when designed to be laid with the cells horizontal and when tested in that position, and 1200 lb. per square inch of gross area when designed to be laid with the cells vertical and when tested in that position.

(b) **Finished Face Tile** shall have an absorption not to exceed 10 per cent and be capable of sustaining a load of at least 700 lb. per square inch of gross area when designed to be laid with the cells horizontal and when tested in that position and 1200 lb. per square inch of gross area when designed to be laid with the cells vertical and when tested in that position.

(c) **Vitrified Foundation Tile** shall have an absorption not exceeding 8 per cent, and be capable of sustaining a load of at least 1200 lb. per square inch over the gross area when tested in the same position as when laid in the wall.

3. Laying

Tile in the exterior walls and interior bearing walls shall be load bearing tile laid to develop their full strength. No vertical or head joints shall be mortared through the wall, but a generous air space shall be left in the center of the walls by buttering the two edges of each tile either before or after it is set in the wall. All tile must be wet before concrete or mortar is placed.

4. Mortar

All mortar used for laying up the hollow tile shall consist of Portland Cement and clean sharp sand in the proportion of one part cement to three parts sand, well mixed to a smooth, moderately stiff mortar. Cold lime putty not to exceed 10 per cent of cement by volume will be allowed in the mortar.

5. Foundation Tile

Where so indicated on the drawings, the foundation walls from top of footings to the underside of first floor beams shall be constructed of hard burned foundation tile. Where columns or piers supporting heavy loads rest on the foundation walls, the wall tile shall be filled with concrete from footing to top of walls.

6. Sub-Dividing Partitions

All partitions shall be started on the structural floor and be wedged against the floor above.

7. Jamb Tile

The Contractor shall provide for all door and window openings where indicated, jamb tile with rabbitted openings to receive the door or window frame box. The space between the tile and the frame box shall be well filled with mortar to within one inch of stop bead and caulked to stop bead with roofers' cement or oakum to prevent the passage of air or moisture.

8. Lintels

Openings not exceeding five feet in clear span may be spanned with arch lintel tile or with regular tile reinforced with proper steel rods in the lower cells and filled solidly with stone concrete.

Openings over five feet in clear span shall be spanned with reinforced concrete or with steel lintels faced with tile, as shown on drawings.

9. Sills

Where called for by the drawings sills of special hollow sill tile shall be used. Special care must be taken to fill all joints so as to prevent moisture working through them; wood sill of window frame shall be set in heavy bed of roofers' cement.

10. Arch Openings

All arch openings shown on drawings shall be spanned with 2-course row-lock hollow brick header arches, carefully laid on substantial centers. Arches shall spring from the hollow tile and must be well bedded on them.

11. Columns and Piers

Columns and piers, so indicated, shall be constructed of hollow tile to sizes shown. Where column finish is round, they shall be built of circular hollow tile column covering filled with concrete where the second story walls are supported by them. Square columns shall be built of the proper size hollow tile laid as indicated under "Laying."

12. Floor Joist Bearings

Tile slabs one inch thick shall be provided and set under all floor joists as bearing plates for end construction tile.

13. Wall Plates

In the upper courses of wall at intervals of 5 feet ¾ inch bolts projecting 6 inches above the top shall be embedded in cement grout to allow the plate being fastened down with washers and nuts.

14. Floors

Floors shall be segmental arch or flat arch of hollow tile construction, as indicated on the drawings.

15. Depth of Tile

Depth of hollow tile shall be regulated by span and load to be carried, and as indicated on the drawings.

16. Centers

Centers must be of such size as to insure against deflecting, and must not be removed before the floor has properly set and under long spans a center line of supports must be maintained for at least three weeks after the floor has been completed.

17. Cleaning, Etc.

Upon completion of this work the Contractor shall repair all damaged tile, clear away all rubbish of every description, leaving this part of the work clean and in perfectly good condition.

18. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed, and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 8

[19]ARCHITECTURAL TERRA COTTA

1. General

The Contractor shall furnish all labor, materials, tools, scaffolding and equipment, except as otherwise noted, necessary to entirely complete any or all classes of architectural terra cotta work herein specified, according to the class of building, and as shown or implied on the drawings.

2. Quality of Material

Material for all architectural terra cotta shall be carefully selected clay, to be in perfect condition after burning, of uniform fracture hard enough to resist scratching by knife.

Architectural terra cotta shall develop an average ultimate compressive strength of not less than 5000 lb. per sq. in.

Coloring shall be as indicated and must be uniform.

3. Defective Work

All work shall be carefully modeled by skilled workmen, in strict accordance with detail drawings. All pieces shall be perfect when set in place and any work damaged after installation, before acceptance, shall be replaced.

4. Drawings

The architectural terra cotta contractor shall prepare and submit to the Engineer, for his approval, complete detail and setting drawings (in triplicate) for all terra cotta work covered by this contract. Such drawings shall show in detail, jointing, bonding, anchoring and other construction features. All blocks shall be numbered serially.

5. Models

If desired by the Engineer full-sized plaster models prepared by experts shall be submitted for his approval. Price for models shall be agreed upon.

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[19] Adopted, Vol. 27, 1926, pp. 1119, 1421.

6. Molding and Fitting

Templates for molded work shall be made according to details and models. Carving and molding work must be sharp, straight, true and well undercut. Blocks must be straight, true and out of wind. A reasonable number of additional blocks must be provided to prevent delay from defective materials or injury. So far as possible all grinding of joints and fitting of material shall be done at the factory. Washes and drips shall be provided for all projecting courses. Wherever flashing occurs raglets shall be provided. Proper provision shall be made for anchors, tie rods, etc.

7. Mortar

Mortar for terra cotta work, unless otherwise specified, shall be composed of one part Portland cement, three parts sand, with the addition of sufficient lime putty to make the mortar work smoothly. The sand and cement shall be mixed dry, then wet to the proper consistency and the lime putty added. Where terra cotta is to be laid with colored mortar, the following mixture shall be used: One part Portland cement, two parts sand, with lime paste added to make it work smoothly and colored with approved mortar color. No more mortar containing cement shall be mixed at any one time than can be used within thirty minutes after mixing. Retempering cement mortar which has begun to set will not be permitted. No mortar which has frozen shall be used on the work.

The cement shall meet the requirements of the American Railway Engineering Association's Specifications for Portland Cement. Cement that has hardened or partially set shall not be used.

Sand shall be clean, sharp, coarse and of grains varying in size. It shall be free from sticks or other foreign matter, but it may contain clay or loam not to exceed two per cent. Where so required for pointing face work, sand shall be clean, sharp, white sand of the very best quality.

Lime used shall be of good quality, in large lumps, free from cinders, or clinkers, must contain less than ten per cent impurities and must slake readily in water, making a very soft paste, free from core. Before being used all lime shall be thoroughly slaked with water. No air-slaked lime shall be used. The use of hydrated lime of approved brand will be permitted at the discretion of the Engineer.

8. Setting and Anchoring

All blocks must be cleaned and wetted before setting.

Mortar shall be kept ½ inch from the face of the terra cotta to allow for pointing. Splashing exposed faces of the terra cotta with mortar shall be avoided.

All beds and vertical joints shall be of maximum width of ⅜ inch unless otherwise indicated. The terra cotta shall be set accurately, true to line and level. Face blocks shall be set on thoroughly wetted wooden wedges, which are not to be removed until the building is cleaned and pointed.

All terra cotta work shall be thoroughly bonded to masonry backing. Cornices, column caps and blocks with greater projection than bed shall be thoroughly anchored.

Anchors and dowels, rods and hooks shall be of the proper size and shape and thoroughly galvanized or coated with asphaltum paint.

This Contractor shall do all cutting and fitting of terra cotta to accommodate other trades.

9. Protection

Wherever necessary, all projecting courses or individual blocks shall be protected against injury during the setting process by wooden covering, which shall be maintained in good and substantial condition until removed for the purpose of cleaning down the work.

10. Cleaning and Pointing

The face of the terra cotta work under this contract shall be thoroughly cleaned upon completion, such cleaning to be done with soap powder boiled in clean water and applied vigorously with stiff fiber brushes. If necessary, clean, sharp, fine white sand may be added to the soap and water mixture. The use of wire brushes or acids will not be permitted for cleaning terra cotta work.

All face joints shall be brushed out ½ inch in depth and pointed flush with mortar consisting of one part stainless cement, two parts clean white sand and sufficient cold lime putty to make a mixture as stiff as can be worked. All joints shall be wetted before pointing.

11. General Conditions

All material entering into the work and all methods used by this Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions, as given in Section 1 of this specification, shall be considered to apply with equal force to this section of the specification.

Section 9

[20]CONCRETE ARCHITECTURAL STONE

1. General

The Contractor shall furnish all labor, tools, material, scaffolding and equipment, except as otherwise noted, necessary to entirely complete any and all classes of concrete architectural stone work herein specified, according to the class of building and as shown on the drawings.

2. Composition

Concrete architectural stone shall be composed of Portland cement, meeting the requirements of the Specifications for Portland Cement of the American Railway Engineering Association, and sound weather-resisting aggregates.

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[20] Adopted, Vol. 27, 1926, pp. 1121, 1421.

3. Tests

Concrete architectural stone shall pass the following test requirements:

(a) **Compression Test.**—The ultimate compressive strength at 28 days must average not less than 1500 lb. per sq. in. of gross cross-sectional area of stone as used in the wall and must not fall below 1000 lb. per sq. in. gross area in any test. The gross area shall be taken as the minimum area in compression.

(b) **Absorption.**—The amount of water absorbed by the stone at 28 days shall not exceed 5 per cent by weight after 24 hours' immersion. (Per cent of absorption is obtained by dividing the weight of the water absorbed by the weight of the dry sample and multiplying the quotient by 100.)

At least three samples shall be tested for compression and three samples for absorption. Whenever practicable, tests shall be made on full-sized samples, but if specimens are too large for testing in the ordinary machine or are in special shapes which cannot be fitted in the machine, smaller or more regular specimens may be used as directed, but these shall be made of the materials and proportions representing fully the manufactured product. The Engineer may require further tests at any time and unless tests are made under the immediate supervision of the Engineer the Contractor shall furnish a certificate of tests made by a laboratory of recognized standing, showing a record of the compressive strength and absorption of the concrete stone.

4. Working Loads and Unit Stresses

Solid walls built of concrete architectural stone laid up in Portland cement mortar may be loaded not to exceed 300 lb. per sq. in. of actual bearing area. Lintels, mullions and other parts carrying heavy loads shall be reinforced with steel sufficient to take the tensile and shearing stresses and shall be designed in accordance with recognized engineering practice. Where local ordinances do not conflict, the design shall be based on a unit tensile stress of 16,000 lb. per sq. in. in reinforcement and 650 lb. per sq. in. compression on the concrete in flexure.

5. Handling

Pieces weighing more than 300 lb. shall be provided with lewis holes or have hooks cast into the stone for hoisting purposes. Hooks shall be laid in flush or arranged to fit into depressions in adjoining stones. Hooks or lewis holes shall not be cast in the face of the stone or come within 2½ inches of the face of the stone unless the stone is less than 5 inches thick.

6. Surface Finish and Carving

A sample or samples of the architectural stone which the Contractor proposes to furnish and erect shall be submitted to the Engineer along with a diagram showing arrangement of joints, various sizes of units and bonding to be employed.

If a surface finish of exposed special aggregate is specified this special facing must be not less than one-half inch thick on the exposed surface. Exposed surfaces shall be rubbed, tooled, scrubbed or acid washed or otherwise treated to expose the aggregate and obtain the desired architectural results. All carving shall be done by skilled carvers from approved models, photographs or drawings.

7. Mortar

The cement shall meet the requirements of the American Railway Engineering Association's Specifications for Portland Cement. Cement that has hardened or partially set shall not be used.

Sand shall be clean, sharp, coarse and of grains varying in size. It shall be free from sticks or other foreign matter, but it may contain clay or loam not to exceed two per cent. Where so required for pointing face work, sand shall be clean, sharp, white sand of the very best quality.

Lime used shall be of good quality, in large lumps, free from cinders, or clinkers, must contain less than ten per cent impurities and must slake readily in water, making a very soft paste, free from core. Before being used all lime shall be thoroughly slaked with water. No air-slaked lime shall be used. The use of hydrated lime of approved brand will be permitted at the discretion of the Engineer.

Mortar for concrete architectural stone work, except where otherwise specified, shall be composed of one part Portland cement and three parts sand, with the addition of sufficient lime putty to make the mortar work smoothly. The sand and cement shall be mixed dry, then wet to the proper consistency, and the lime putty added. Where colored mortar is to be used, the mortar shall be composed of one part Portland cement, and two parts sand, with lime putty added to make it work smoothly, and colored with approved mortar color. No more mortar shall be mixed at any one time than can be used within 30 minutes after mixing. Retempering cement mortar which has begun to set shall not be permitted. Mortar that has frozen shall not be used on the work.

8. Anchors and Dowels

Where anchors and dowels are required they shall be of the proper size and shape, thoroughly galvanized or painted with asphaltum paint.

9. Setting

Stone shall be thoroughly cleaned on all joints before setting. The exposed faces of the stone shall not be splashed with mortar. All beds and vertical joints shall be a minimum thickness of ¼ inch unless otherwise indicated. The stone shall be set true to line and level. These stones shall be set on thoroughly wetted wooden wedges which shall not be removed until the building is cleaned and pointed. The ends only of sills shall be set in a full bed of mortar, leaving the remainder of sills free until pointed.

10. Cleaning and Pointing

The face of concrete architectural stone shall be thoroughly cleaned upon completion. The use of acids will not be permitted for cleaning unless specifically directed by the Engineer.

All face joints shall be raked out ¾ inch in depth and pointed flush with mortar consisting of one part Portland cement, two parts of clean white sand and only sufficient cold lime putty to make a workable mixture, or with colored mortar as specified in Article 7.

11. Protection

Wherever necessary, all projecting courses or individual blocks shall be protected against injury during the setting process by wooden covering, same to be maintained in good and substantial condition until removed for the purpose of cleaning down the work.

12. Guarantee

The Contractor for concrete architectural stone shall guarantee the surface to be free from efflorescence, crazing, crumbling or fading for a period of two years after completion of the building.

13. General Conditions

All material entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 10-A

[21]CONCRETE ROOFING TILE

1. General

The Contractor shall furnish all labor, materials, tools and equipment needed to entirely complete the concrete roofing tile, including all valleys and flashing as specified or shown on drawings.

2. Types

Concrete roofing tile shall be divided into the following types:

- (1) Small tile supported directly on roofing paper and roof sheathing.
- (2) Large tile spanning between purlins.

  Large tile shall be specified as:
    - (a) Interlocking tile for pitched roofs and
    - (b) Flat tile.

3. Materials

Concrete roofing tile shall be composed of Portland cement in accordance with Specifications for Portland Cement of the A.R.E.A., and clean, hard coarse sand or crushed rock. Large tile shall have suitable metal reinforcement. If colored tile are specified, the color must be obtained by the use of pure mineral oxides, pure red oxide of iron for red, and chromium oxide for green. The coloring material shall be reground with the cement in a small ball mill or other closed grinder so that at least 78 per cent of the combined cement and coloring material will pass a 200-mesh sieve as determined by samples.

4. Manufacture

Small concrete roofing tile shall be made on approved cast iron or strong steel pallets and upon an improved machine developing a pressure at the rollers or tampers of at least 100 lb. per sq. in. Pallets shall be straight and free from warps. Large tile shall be made in smooth substantial molds to produce tile true to dimensions. Troweling bars shall have tapered channels which produce a compressive action.

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[21]Adopted, Vol. 27, 1926, pp. 1124, 1422.

The colored cement for colored tile shall be either mixed with sand and deposited as a facing in the molds or dusted dry onto the face of the tile and troweled in by special shaped tools or rollers to give a dense, permanent even colored surface, or else applied in liquid form as the tile leaves the rollers.

As the tile are taken from the machine or molds the lower edge shall be painted with a mixture of colored cement and water applied with a brush, except where color is incorporated into or through the body of the tile when painting may be omitted. Tile shall stand for not less than three hours on cars or racks before placing in curing chambers and shall be cured preferably in moist steam or under fog nozzles for 24 hours. In cold weather the temperature in the curing chamber shall be maintained not less than 75 degrees Fahr. The tile shall then be taken from the pallet and stacked on end, kept under cover for 10 days and well wetted down at least twice a day. They shall then be stacked in the open air for 20 days more and sprinkled daily.

5. Dimensions

Tile shall be true and of even thickness. The thickness of small concrete tile shall be not less than $\frac{3}{16}$ inch and edges and ends shall be smooth and clean. Tile shall be not warped more than ⅛ inch and shall not vary more than $\frac{1}{16}$ inch in thickness. Starter tile shall be flanged and eave tile shall be made on special pallets that show solid edges.

Interlocking tile shall be .... by .... inches and one inch thick for the flat portion. The surface exposed to the weather shall be .... by .... allowing 4-inch end laps.

The tile must weigh not over 16 lb. per sq. ft. and shall not vary from the specified thickness more than $\frac{1}{16}$ inch nor be warped more than ⅛ inch.

Large flat tile shall be .... by .... in. and 1½ inches thick. The ends of the tile shall be recessed so as to shoulder on the supports. The tile shall not weigh over 17 lb. per sq. ft. and shall not vary in thickness more than $\frac{1}{16}$ inch nor be warped more than ⅛ inch.

6. Tests

All tests shall be made in a laboratory of recognized standing and a certified copy of the tests shall be furnished by the manufacturer. Tests shall be on full sized samples and at least six samples representing the ordinary commercial product shall be tested.

Concrete roofing tile shall not absorb more than 5 per cent of its own weight of water in 24 hours. Absorption from the face of the tile shall not exceed two per cent by weight in 24 hours with the face of the tile sample in contact with the water.

Tile shall be tested with weather face up. The tile shall be supported under the lugs near the ends of the tile if the tile have lugs, but in no test shall the span be less than 13 inches for small tile nor less than .... inches for large tile. The support under one end shall be rigid and the support under the other end shall rest on a roller bearing to allow for variation in the under surface of the tile. The load for small tile shall be applied in the center of the tile by placing a rigid bar having a semi-circular bearing midway between the supports. From this cross-bar shall be suspended a bucket-like receptacle which shall be loaded with shot, sand or other suitable material until the tile breaks. The breaking load shall average not less than 150 lb. per tile when the load is applied in accordance with the method described above.

Large interlocking tile shall withstand a uniformly distributed load of 100 lb. per sq. ft.

Flat tile shall withstand a uniformly distributed load of 150 lb. per sq. ft. when supported on supports .... feet apart.

Lots of tile intended for building construction may be rejected if more than 10 per cent of the samples tested break at loads less than 100 lb. per sq. ft.

7. Laying

Small roofing tile shall be laid in accordance with the following specifications:

Over the sheathing apply approved felt roofing paper, weighing not less than 14 lb. per sq. ft. laid parallel to eaves. Cap all hips longitudinally with extra ply of felt at least 12 inches wide. In valleys lay one extra ply full sheet wide, longitudinally. Where felt extends against vertical walls, it shall be carried at least 6 inches on vertical surface under counter flashing. The roof shall be water-tight after applying the felt. Over felting $\frac{3}{16}$-inch lath shall be laid on 18-inch centers from eave to ridge. Nailing strips ¾ by 1¾ inches shall be nailed above lath. The roof shall be accurately laid out with rule and chalk line by the roofer and when finished, courses shall present a straight and uniform appearance when viewed vertically, horizontally or diagonally. All hip and ridge roll shall be laid accurately and bedded in 1:3 Portland cement mortar colored with approved mineral color to match balance of roof.

Large interlocking tile shall be self-fastening and shall be held in place by a hanger at the upper end, and laid on purlins spaced as directed by the manufacturer. The tile shall lock sideways by means of the side roll and rabbet, which shall be integral parts of the tile. Gable ends shall be finished with end finishing tile with the tile wing flat against the end walls of the building. Where gable end walls extend above the roof the roofing Contractor shall arrange that a 4 by 4 inch chase at the line of the top of purlins be provided for the reception of the tile. The roof ridge shall be finished with an interlocking ridge roll of the same material as the standard tile, properly cemented to the main roof. The spacing between tops of ridge purlins shall not exceed 8 inches. Hip roofs shall be finished with interlocking hip roll of same material as standard tile and laid in Portland cement to fit tightly on main roof. Bearing for interlocking hip roll shall be provided to height of purlin tops to properly support the roof tile.

Where necessary, flashing plate of the same material as the standard tile shall be provided. All tile when laid shall be properly pointed with cement.

The joints of large flat tile shall be pointed where necessary so as to provide a smooth surface for the application of the composition roofing which is to be applied with a high-melting-point adhesive.

Gutters for pitched roofs shall be formed with standard reinforced flat tile to conform with drawings.

8. Provision for Ventilation

Provision shall be made for the proper ventilation for the underside of tile roofing to prevent the formation of condensation.

9. Guarantee

The Roofing Contractor shall furnish an unqualified guarantee, with good and sufficient bond, covering the maintenance of the roof in a watertight condition for a period of .... years from date of completion.

10. General Conditions

All material entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 10-B

[22]CLAY ROOFING TILE

1. General

The Contractor shall furnish all labor, material, tools, scaffolding and equipment, unless otherwise noted, necessary to complete any or all classes of clay roofing tile, herein specified, according to the class of building and as shown or implied on the drawings.

2. Materials

All pitched roofs so indicated on the drawings shall be covered with .... pattern clay tile, as made by ...., or approved equal, with stock fittings, suitable for each pattern.

Clay tile shall be hard burned, true in shape and of uniform natural deep color, in accordance with samples submitted to and approved by the Engineer. The Contractor shall submit with his bid representative samples of the clay tile to be used, and the tiles subsequently furnished must be equal in quality to the samples.

3. Flashings

All raglets or special flashing tiles of every description, in connection with this roof, shall be furnished and placed by this Contractor. Metal flashings will be furnished and placed by the sheet metal contractor.

4. Roofing Felt

The roofer shall cover the roof sheathing with one thickness of approved roofing felt weighing not less than .... lb. to the square, laying same with a 3-inch lap and securing in place with capped nails not over 10 inches apart. The felt should be laid parallel with the eaves and lapped over all valleys about 4 inches and laid under all hips and ridge flashings about 6 inches.

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[22] Adopted, Vol. 27, 1926, pp. 1127, 1422.

5. Laying Tile

Tiles shall be fastened with copper nails, and shall be well locked together and lay smoothly, and no attempt shall be made to stretch the courses.

The tiles must be laid so that the vertical lines are parallel with each other and at right angles to the eaves. The tiles that verge along the hips shall be cut close against the hip boards, and a water-tight joint made by cementing cut hip joint to hip board with best quality elastic cement. Each piece of hip roll shall then be nailed to the hip board and the hip rolls cemented where they lap each other. No broken or cracked tiles shall be used or left in the roof when complete.

Gable rakes shall be furnished with special detached gable rake fittings.

6. Guarantee

The Roofing Contractor shall furnish an unqualified guarantee, with good and sufficient bond, covering the maintenance of the roof in a watertight condition for a period of .... years from date of completion.

7. General Conditions

All material entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 10-C

[23]SLATE ROOFING

1. General

The Contractor shall furnish all labor, tools, material, equipment and everything necessary to entirely complete the slate roofing shown on the drawings together with all slate covering on sides of dormers and other vertical surfaces where so indicated.

2. Materials

(a) SLATE: The slate shall be No. ...., ... They shall be .... inches by .... inches in size, ... inches thick and .... in color.

All slate shall be hard, dense, sound rock, machine punched for two nails each, for nailing above top edge of second course below.

Exposed corners shall be practically full. No broken corners on covered ends, which sacrifice nailing strength or the laying of a watertight roof will be allowed. No broken or cracked slates shall be used. Samples of slate shall be submitted for approval before ordering and all slate shall conform with the approved samples.

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[23] Adopted, Vol. 28, 1927, pp. 685, 1419.

(b) ROOFING FELT: The felt to be used with slate roofs shall be asphalt saturated rag felt, weighing not less than 14 pounds per 108 square feet. It shall be sufficiently pliable to meet the requirements of application, and samples taken five feet from the outside ends of the rolls, shall bend flat without cracking through 180 degrees at a temperature of 60 degrees.

(c) NAILS: All nails shall be large headed solid copper or yellow metal slaters' nails, 1¼ inch for slates 18 inches or less in length and 1½ inches for slates longer than 18 inches.

3. Application

The roof deck shall be clean, smooth, thoroughly dry and free from projections which would injure the roof covering. The roofing felt shall be laid smoothly, without wrinkles or buckles, and finished surfaces shall be free from cracks and bubbles.

Before applying the roofing felt, all loose knots and other flaws shall be removed and knot-holes and large cracks shall be covered with tin or other sheet metal, nailed in place.

The roofing felt shall first be applied to the roof sheathing, starting at the eaves. All joints shall be lapped two (2) inches, and the felt shall be securely tacked to the sheathing.

The slate shall be laid in horizontal courses, with 3-inch head lap over the second course below and each course shall break joints with the preceding one. Each slate shall be fastened with two nails, driven so that the next course will not ride the nail heads. Slates at eaves or cornice line shall be doubled and canted ¼ inch by a wooden cant strip.

Hips shall have a concealed sheet metal flashing laid with each slate. Slate at valleys and hips shall be laid in elastic cement of the same color as the slate.

Slate over-lapping sheet metal shall have the nails so placed as to avoid puncturing the sheet metal.

All valleys, roof edges and hips shall be carefully fitted and lined. Slate shall be carefully fitted to all wall flashings and at ridges to receive ridge roll or cresting. Small pieces of slate at valleys and hips will not be allowed. Slate should project one inch over edge at gable ends or eaves where gutter is omitted.

Under eaves and top courses shall be of same width and with grain of slate vertical. No stretchers or slate with grain running horizontal will be permitted.

Slate shall be neatly fitted around all pipes, ventilators, etc. Hips, ridges and valleys shall be built as called for on the drawings.

The Slating Contractor shall build in and place all flashing pieces furnished by the Sheet Metal Contractor and co-operate with him in doing the work of flashing.

On completion, all slate must be sound, whole and clean, and the roof shall be watertight.

4. Sheet Metal Work

Flashings and other sheet metal work in connection with slate roofing shall be furnished and installed in accordance with the Specifications for "Sheet Metal Work," as shown in Section 11 of this specification.

5. Guarantee

Upon completion of the work the Contractor shall furnish a written guarantee covering the maintenance of the slate roofing in a watertight condition for a period of one year from date of acceptance, replacing or repairing any broken slates or leaks, promptly as notified, until the end of the guarantee period.

6. General Conditions

All materials entering into the work, and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 10-D

[24]BUILT-UP ROOFING

MATERIALS

1. General

The Contractor shall furnish all labor, material tools and equipment necessary to entirely complete the Roofing, to make the work watertight, and shall leave it in a neat and finished condition.

2. Materials

PITCH.—Pitch shall be the best quality, straight-run American coal-tar pitch, distilled direct from coal-tar and free from water and ammonia. It shall contain not less than 15 per cent nor more than 35 per cent of free carbon. The melting point shall be not below 140 degrees Fahr. nor above 150 degrees Fahr. (A.S.T.M. cube method) and it shall show a flashpoint of not less than 240 degrees Fahr.

ASPHALT.—Asphalt shall be a combination of natural asphalt prepared and combined properly in which inherent mineral matter will be permitted but to which no mineral matter shall be added. The melting point of asphalt shall be between 140 degrees Fahr. and 180 degrees Fahr. The penetration at 77 degrees Fahr. under a load of 100 grams for 5 seconds shall be not less than 20 or more than 30. The ductility at 77 degrees Fahr., when a briquette of the material having a minimum cross-section of 1 centimeter is pulled apart at the rate of 5 centimeters per minute, shall be not less than 10 centimeters for asphalt having a melting point under 165 degrees Fahr., nor less than 3 centimeters for asphalt having a melting point between 165 degrees Fahr. and 180 degrees Fahr. The loss of a 50 gram sample at 325 degrees Fahr. for 5 hours shall not exceed 1 per cent. The penetration of the residue at 77 degrees Fahr. under a load of 100 grams for 5 seconds shall be not less than 10 nor more than 15. The methods of making tests shall be in accordance with the standard of the A.S.T.M., and penetrations are in hundredths of a centimeter.

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[24] Adopted, Vol. 26, 1925. pp. 462, 1316; Vol. 27, 1926, pp. 1129, 1200, 1421.

ASPHALT PRIMER.—Asphalt primer for concrete and gypsum decks shall weigh not less than 7 lb. per gallon and shall be made from asphalt, of the quality specified under "Asphalt" flushed to the proper consistency. The melting point of the asphalt primer shall be such as will permit the subsequent application of hot asphalt to amalgamate immediately with it.

ROOFING FELTS.—Impregnated felts shall be 32 or 36 inches wide and shall be saturated thoroughly. They shall have sufficient pliability to meet the requirements of application, and samples taken 5 feet from the outside ends of rolls shall bend flat without cracking through 180 degrees at a temperature of 60 degrees Fahr. A variation of 7 per cent from the weights specified will be allowed. The impregnating compounds shall be of the qualities specified and shall be of the proper consistency for saturating the felts.

Tarred and asphalted felts shall be rag felts, and for built-up roofings shall weigh not less than 14 lb. per 108 sq. ft.

Unimpregnated felt or rosin-sized building paper shall weigh not less than 5 lb. per 108 sq. ft.

MANUFACTURED ROOFING.—Manufactured roofing material shall be delivered at the site in the original sealed packages of the manufacturer, and each package shall be wrapped and labeled properly in order that it may be identified easily.

GRAVEL AND SLAG.—Gravel shall be hard, durable, free from clay, loam, and other foreign substances, and shall range from ¼ to ⅝ inch.

Slag shall be a granulated furnace slag, free from sand, dirt and other foreign substances, and shall range from ¼ to ⅝ inch.

3. Application

The roof decks shall be clean, smooth, thoroughly dry and free from projections which would injure the roof coverings. All roofing shall be laid smoothly, without wrinkles or buckles, and finished surfaces shall be free from cracks and bubbles.

Before applying the roofing over wood decks, all loose knots and other flaws shall be removed and knot holes and large cracks shall then be covered with tin or other sheet metal nailed in place.

For gypsum or concrete decks, the joints and surfaces shall be made tight and flush, and all loose and uneven surfaces shall be leveled up before the roofing is applied.

TYPE A-1

Pitch and Gravel (or Slag) Over Wood or Pre-Cast Gypsum Slabs

> Roofing constructed of five layers of tarred felt, pitch and gravel (or slag) and a minimum of 150 lb. of pitch per 100 sq. ft.

(1) If on wood, lay one thickness of rosin-sized building paper or unimpregnated felt weighing not less than 5 lb. per 108 sq. ft., lapping the sheets at least one inch; if on pre-cast gypsum, this shall be omitted.

(2) Over the entire surface lay two layers of tarred felt, weighing not less than 14 lb. per 108 sq. ft. per layer, lapping each sheet of each layer 17 inches over the preceding sheet, end laps not less than 4 inches.

Sheets shall be nailed as often as necessary to hold them in place until the remaining felt is laid. These layers shall be turned up vertical surfaces not less than 6 inches and securely fastened.

(3) Coat the entire surface uniformly with hot pitch, using not less than 25 lb. per 100 sq. ft.

(4) Over the entire surface lay three layers of tarred felt, lapping each sheet of each layer 22 inches over the preceding sheet, with end laps not less than 6 inches. Hot pitch shall be mopped the full 22 inches on each sheet so that in no place shall felt touch felt, using not less than 25 lb. of pitch per 100 sq. ft. between successive layers. Any nailing necessary shall be done in such a manner that all nails will be covered by not less than two layers of felt. Nails shall be galvanized and shall be driven through flat tin or zinc caps. These layers shall be turned up vertical surfaces not less than 6 inches and securely fastened.

(5) Coat the entire surface uniformly with hot pitch poured from a dipper, using not less than 75 lb. per 100 sq. ft., into which while hot embed not less than 400 lb. of gravel (or 300 lb. of slag).

TYPE A-2

Pitch and Gravel (or Slag) Over Concrete or Poured Gypsum

> Roofing constructed of one coating hot pitch and five layers of tarred felt, pitch and gravel (or slag) and a minimum of 215 lb. of pitch per 100 sq. ft.

(1) The entire surface shall be coated uniformly with hot pitch, using not less than 40 lb. per 100 sq. ft.

(2) Over this lay two layers of tarred felt, weighing not less than 14 lb. per 108 sq. ft. per layer, lapping each sheet of each layer 17 inches over the preceding sheet, end laps not less than 4 inches. Hot pitch shall be mopped the full 17 inches on each sheet, so that in no place will felt touch felt, using not less than 25 lb. of pitch per 100 sq. ft. between successive layers. These layers shall be turned up vertical surfaces not less than 6 inches and securely fastened.

(3) Coat the entire surface uniformly with hot pitch using not less than 25 lb. per 100 sq. ft.

(4) Over the entire surface lay three layers of tarred rag felt, lapping each sheet of each layer 22 inches over the preceding sheet, end laps not less than 6 inches. Hot pitch shall be mopped the full 22 inches on each sheet, so that in no place will felt touch felt, using not less than 25 lb. of pitch per 100 sq. ft. between succeeding layers.

If roof decks are of gypsum, in addition to the above, the upper edge of each course of the third layer of felt shall be nailed to the roof deck with galvanized nails driven through flat tin or zinc caps. These layers shall be turned up vertical surfaces not less than 6 inches and securely fastened.

(5) Coat the entire surface uniformly with hot pitch poured from a dipper, using not less than 75 lb. per 100 sq. ft., into which while hot not less than 400 lb. of gravel (or 300 lb. of slag) shall be embedded.

TYPE B-1

Asphalt and Gravel (or Slag) Over Wood or Pre-Cast Gypsum Slabs

Roofing constructed of five layers of asphalted felt, asphalt and gravel (or slag) and a minimum of 150 lb. of asphalt per 100 sq. ft.

(1) If on wood, lay one thickness of rosin-sized building paper or unimpregnated felt weighing not less than 5 lb. per 100 sq. ft., lapping the sheets at least one inch; if on pre-cast gypsum this shall be omitted.

(2) Over the entire surface lay two layers of asphalted felt, weighing not less than 14 lb. per 108 sq. ft. per layer, lapping each sheet of each layer 17 inches over the preceding sheet, end laps not less than 4 inches. Sheets shall be nailed as often as necessary to hold them in place until the remaining felt is laid. These layers shall be turned up vertical surfaces not less than 6 inches and securely fastened.

(3) Coat the entire surface uniformly with hot asphalt, using not less than 25 lb. per 100 sq. ft.

(4) Over the entire surface lay three layers of asphalted felt, lapping each sheet of each layer 22 inches over the preceding sheet, end laps not less than 6 inches. Hot asphalt shall be mopped the full 22 inches on each sheet, so that in no place will felt touch felt, using not less than 25 lb. of asphalt per 100 sq. ft. between successive layers.

Any nailing necessary shall be done in such manner that all nails will be covered by not less than two layers of felt. Nails shall be galvanized and shall be driven through flat tin or zinc caps. These layers shall be cut off at vertical surfaces not less than 6 inches and securely fastened.

(5) Coat the entire surface uniformly with hot asphalt poured from a dipper, using not less than 75 lb. per 100 sq. ft., into which while hot embed not less than 400 lb. of gravel (or 300 lb. of slag).

TYPE B-2

Asphalt and Gravel (or Slag) Over Concrete or Poured Gypsum

Roofing constructed of five layers asphalted felt, asphalt and gravel (or slag) and a minimum (not including primer) of 205 lb. of asphalt per 100 sq. ft.

(1) The entire surface, if of concrete, shall be coated uniformly with asphalt primer, using not less than 10 lb. per 100 sq. ft. and allowed to dry.

(If of gypsum, the surface shall be given two such coats.) Upon this there shall be applied a uniform coat of hot asphalt, using not less than 30 lb. per 100 sq. ft.

(2) Over this lay two layers of asphalted rag felt, weighing not less than 14 lb. per 108 sq. ft. per layer, lapping each sheet of each layer 17 inches over the preceding sheet; end laps not less than 4 inches and securely fastened. Hot asphalt shall be mopped the full 17 inches on each sheet, so that in no place will felt touch felt, using not less than 25 lb. of asphalt per 100 sq. ft. between successive layers. These layers shall be turned up vertical surfaces not less than 6 inches and securely fastened.

(3) Coat the entire surface uniformly with hot asphalt, using not less than 25 lb. per 100 sq. ft.

(4) Over the entire surface lay three layers of asphalted rag felt, lapping each sheet of each layer 22 inches over the preceding sheet, end laps not less than 6 inches. Hot asphalt shall be mopped the full 22 inches on each sheet, so that in no place will felt touch felt, using not less than 25 lb. of asphalt per 100 sq. ft. between successive layers.

If roof decks are of gypsum, in addition to the above, the upper edge of each course of the third layer of felt shall be nailed to the roof deck with galvanized nails driven through flat tin or zinc caps. These layers shall be turned up vertical surfaces not less than 6 inches and securely fastened.

(5) Coat the entire surface uniformly with hot asphalt poured from a dipper, using not less than 75 lb. per 100 sq. ft., into which while hot embed not less than 400 lb. of gravel (or 300 lb. of slag).

Type "C1" (Class A)

Asphalt Impregnated Asbestos Felt and Asphalt Cement Over Wood

Roofing composed of one layer approximately 60 lb., two layers approximately 14 lb., asphalt impregnated asbestos felt (the latter lapped 17 inches), and a minimum of 85 lb. asphalt roofing cement, per 100 sq. ft.

1. Lay sheets of asphalt impregnated asbestos felt weighing approximately 60 lb. per 108 sq. ft. directly over the sheathing. Lap the joints 3 inches and seal them with asphalt cement. Nail these sheets along the lap with barbed nails driven through flat tin caps, spaced 6 inches apart, and in parallel lines approximately 10 inches apart and approximately 10 inches from the laps, these nails to be spaced 18 inches apart and staggered. This 60 lb. felt shall be laid parallel to pitch of roof and turned up 5 inches above level of roof on all vertical surfaces, but not cemented to vertical surfaces.

Over the 60 lb. felt, edging strips composed of the flashing material shall be applied at eaves and gable overhang, extending 4 inches on roof, cemented and nailed, and turned down over and secured to facia and projected ½ inch beyond to form a drip edge.

2. Mop the entire surface of the 60-lb. felt with the asphalt cement, heated to flow freely, and while the cement is hot, embed in it sheets of asphalt impregnated asbestos felt, weighing approximately 14 lb. per 108 sq. ft., in two-ply construction; this 14 lb. felt to be run at right angles to the 60 lb. felt, lapped 17 inches and turned up 5 inches above level of roof, on all vertical surfaces.

Start at low point of roof with a one-half width sheet of the 14 lb. felt, then a full width sheet of the same felt laid flush with and entirely covering the one-half width sheet. Then lay full width sheets, setting the first so as to overlap the one-half width starting sheet 2 inches and then exposing 15 inches of each succeeding sheet to the weather.

Mop the entire surface between plies with the asphalt cement, heated to flow freely, and roll the felts closely behind the mop so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per square for each mopping.

Nail the back edge of each sheet with the barbed nails, driven through flat tin caps, spaced 9 inches apart; the center line of nail heads to be approximately ¾ inch below back edge of sheet.

3. Wall and all other elevations above roof surface shall be carried vertically at least 12 inches to provide for proper flashing. Roofing material shall be carried up 5 inches above level of roof on all vertical surfaces.

All flashings, except those around ventilators, standpipes, exhausts, etc., shall be composed of base flashing of special asbestos flashing material, approximately 10½ inches wide, cemented and nailed to vertical surface. Such flashings shall be counter-flashed with approved fibrous mineral and bituminous cement and applied with a reinforcement of impregnated asbestos felt.

4. When the roofing is otherwise complete, cover the entire surface with a mopping of the asphalt cement, to be applied hot, using approximately 25 lb. to the square.

TYPE "C1" (CLASS B)

Asphalt Impregnated Asbestos Felt and Asphalt Cement Over Wood

Roofing composed of one layer approximately 60 lb., one layer approximately 14 lb., asphalt impregnated asbestos felt (the latter lapped 3 inches), and a minimum of 55 lb. asphalt roofing cement, per 100 sq. ft.

1. Lay sheets of asphalt impregnated asbestos felt, weighing approximately 60 lb. per 108 sq. ft., directly over the sheathing. Lap the joints 3 inches and seal them with asphalt cement. Nail these sheets along the lap with barbed nails driven through flat tin caps, spaced 6 inches apart, and in parallel lines approximately 10 inches apart and approximately 10 inches from the laps; these nails to be spaced 18 inches apart and staggered. This 60 lb. felt shall be laid parallel to pitch of roof and turned up 5 inches above level of roof on all vertical surfaces, but not cemented to vertical surfaces.

Over the 60 lb. felt, edging strips composed of the flashing material shall be applied at eaves, and gable overhang, extending 4 inches on roof, cemented and nailed and turned down over and secured to facia, and projected ½ inch beyond to form a drip edge.

2. Mop the entire surface of the 60 lb. felt with the asphalt cement, heated to flow freely, and while the cement is hot, embed into it sheets of asphalt impregnated asbestos felt, weighing approximately 14 lb. per 108 sq. ft., in single ply construction; this 14 lb. felt to be run at right angles to the 60 lb. felt, lapped 3 inches and turned up 5 inches above level of roof on all vertical surfaces.

Start at low point of roof with a one-half width sheet of the 14 lb. felt, then a full width sheet of the same felt laid flush with and entirely covering the one-half width sheets. Then lay full width sheets, overlapping the preceding ones 3 inches, with balance exposed to the weather.

Mop the entire surface between plies with the asphalt cement, heated to flow freely, and roll the felts closely behind the mop so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per square for each mopping.

Nail the back edge of each sheet with the barbed nails, driven through flat tin caps spaced 9 inches apart; the center line of nail heads to be approximately ¾ inch below back edge of sheet.

3. Walls and all other elevations above roof surface shall be carried vertically at least 12 inches to provide for proper flashing. Roofing material shall be carried up 5 inches above level of roof on all vertical surfaces.

All flashings, except those around ventilators, standpipes, exhausts, etc., shall be composed of base flashing of special asbestos flashing material, approximately 10½ inches wide, cemented and nailed to vertical surface. Such flashings shall be counterflashed with approved fibrous mineral and bituminous cement and applied with a reinforcement of impregnated asbestos felt.

4. When the roofing is otherwise complete, cover the entire surface with a mopping of the asphalt cement, to be applied hot, using approximately 25 lb. to the square.

TYPE "C2" (CLASS A)

Asphalt Impregnated Asbestos Felt and Asphalt Cement Over Dry Concrete or Gypsum

Roofing composed of one coat asphalt primer, one coat asphalt cement over primer, one layer, approximately 60 lb., and two layers approximately 14 lb., asphalt impregnated asbestos felt (the latter lapped 17 inches), and a minimum of 85 lb. asphalt roofing cement per 100 sq. ft., not including primer or first coat over primer.

1. Coat the concrete or gypsum with cold asphalt primer, using approximately one gallon over concrete and one to two gallons over gypsum per 100 sq. ft. of roof surface to provide a proper bond between roof deck and asphalt. Allow the primer to dry.

2. Mop the entire surface thus primed with asphalt cement, heated to flow freely, and while the cement is hot embed into it sheets of asphalt impregnated asbestos felt, weighing approximately 60 lb. per 108 sq. ft. Lap the joints 3 inches and seal them with the hot asphalt cement. The 60 lb. felt shall be laid parallel to pitch of roof and turned up 5 inches above level of roof on all vertical surfaces.

Over the 60 lb. felt, edging strips composed of flashing materials shall be applied at eaves and gable overhang, extending 4 inches on roof, cemented and turned down over and secured to facia and projected ½ inch beyond to form a drip edge.

3. Mop the entire surface of the 60 lb. felt with the hot asphalt cement, and while the cement is hot embed into it sheets of asphalt impregnated asbestos felt, weighing approximately 14 lb. per 108 sq. ft. in two-ply construction; this 14 lb. felt to be run at right angles to the 60 lb. felt, lapped 17 inches and turned up 5 inches above level of roof on all vertical surfaces.

Start at low point of roof with a one-half width sheet of the 14 lb. felt, then a full width sheet of the same felt laid flush with and entirely covering the one-half width sheet. Then lay full width sheets, setting the first so as to overlap the one-half width starting sheet 2 inches and then exposing 15 inches of each succeeding sheet to the weather.

Mop the entire surface between plies with asphalt cement, heated to flow freely, and roll the felts closely behind the mop so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per square for each mopping.

4. On gypsum and other types of roof decks that permit of nailing, the back edges of all felts shall be securely nailed to roof slab with cut nails driven through flat tin caps in addition to mopping.

5. Walls and all other elevations above roof surface shall be carried vertically at least 12 inches to provide for proper flashing.

Roofing material shall be carried up 5 inches above level or roof on vertical surfaces. All flashings except those around ventilators, standpipes, exhausts, etc., shall be composed of base flashing of special asbestos flashing material approximately 10½ inches wide, cemented and nailed to vertical surface. Such flashings shall be counterflashed with approved fibrous mineral and bituminous cement, and applied with a reinforcement of impregnated asbestos felt.

6. When the roofing is otherwise complete, cover the extreme surface with a mopping of the asphalt cement, to be applied hot, using approximately 25 lb. to the square.

NOTE.—On concrete surfaces maximum pitch upon which this roofing may be applied without nailing is 3 inches to the foot, except on short runs, as in sawtooth construction. If wood nailing strips are inserted in concrete, the pitch may be increased.

Provision for expansion should be made in covering over expansion joints in concrete slab.

TYPE "C2" (CLASS B)

Asphalt Impregnated Asbestos Felt and Asphalt Cement Over Dry Concrete or Gypsum

Roofing composed of one coat of asphalt primer, one coat asphalt cement over primer, one layer approximately 60 lb., and one layer approximately 14 lb. asphalt impregnated asbestos felt (the latter lapped 3 inches) and a minimum of 55 lb. asphalt roofing cement per 100 sq. ft., not including primer or first coat over primer.

1. Coat the concrete or gypsum with cold asphalt primer, using approximately 1 gallon over concrete and 1 to 2 gallons over gypsum per 100 sq. ft. of roof surface to provide a proper bond between roof deck and asphalt. Allow the primer to dry.

2. Mop the entire surface thus primed with asphalt cement, heated to flow freely, and while the cement is hot, embed in it sheets of asphalt impregnated asbestos felt, weighing approximately 60 lb. per 108 sq. ft. Lap the joints 3 inches and seal them with the hot asphalt cement. This 60 lb. felt shall be laid parallel to pitch of roof and turned up 5 inches above level of roof on all vertical surfaces, but not cemented to vertical surfaces.

Over the 60 lb. felt, edging strips composed of flashing material shall be applied at eaves and gable overhang, extending 4 inches on the roof, cemented and turned down over and secured to facia and projected ½ inch beyond, to form a drip edge.

3. Mop the entire surface of the 60 lb. felt with the hot asphalt cement, and while the cement is hot, embed into it sheets of asphalt impregnated asbestos felt, weighing approximately 14 lb. per 108 sq. ft. in single-ply construction; this 14 lb. felt to be run at right angles to the 60 lb. felt, lapped 3 inches and turned up 5 inches above level of roof on all vertical surfaces.

Start at low point of roof with a one-half width sheet of the 14 lb. felt, then a full width sheet of the same felt laid flush with and entirely covering the one-half width sheet. Then lay full width sheets, overlapping the preceding ones 3 inches, with the balance exposed to the weather.

Mop the entire surface between plies with the asphalt cement, heated to flow freely, and roll the felts closely behind the mop so that no missing of asphalt can possibly take place. Approximately 30 lb. of asphalt shall be used per square for each mopping.

4. On gypsum and other types of roof decks that permit of nailing, the back edges of all felt shall be securely nailed to roof slab with cut nails driven through flat tin caps in addition to mopping.

5. Walls and all other elevations above roof surface shall be carried vertically at least 12 inches to provide for proper flashing.

Roofing material shall be carried up 5 inches above level of roof on all vertical surfaces. All flashings except those around ventilators, standpipes, exhausts, etc., shall be composed of base flashing of special asbestos flashing material, approximately 10½ inches wide, cemented and nailed to vertical surface. Such flashings shall be counterflashed with approved fibrous mineral and bituminous cement and applied with a reinforcement of impregnated asbestos felt.

When the roofing is otherwise complete, cover the entire surface with a mopping of the asphalt cement, to be applied hot, using approximately 25 lb. to the square.

Note.—On concrete surfaces maximum pitch upon which this roofing may be applied without nailing is 3 inches to the foot, except on short runs, as in sawtooth construction. If wood nailing strips are inserted in concrete, the pitch may be increased.

Provision for expansion should be made in covering over expansion joints in concrete slab.

4. Guarantee

The Roofing Contractor shall furnish an unqualified guarantee, with good and sufficient bond covering the maintenance of the roof in a watertight condition for a period of .... years from date of competion.

5. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 11

[24]SHEET METAL WORK

1. General

Under this heading shall be included all sheet metal gutters, cornices, rain conductors, flashings, valleys, eave strips and gravel stops, ridge rolls and hip capping, roof pans, conductor outlets and heads, skylights, ventilators and all other sheet metal work shown on the drawings or necessary to complete the building.

2. Materials

Sheet metal work shall be copper, galvanized iron, lead or rolled zinc as shown on the drawings, or as specifically called for in the contract.

Copper.—Cooper sheets shall be rolled from copper conforming to the specifications of the A.S.T.M. and marked with the weight and manufacturers' name. Copper flashings, valleys, eave strips and roof pans shall be 16 ounce soft rolled copper.

Copper rain conductors, eave troughs, moulded and hanging gutters and conductor heads shall be 16 ounce cold drawn, or hard copper.

Copper cornices shall be 20 ounce cold rolled or hard copper.

Galvanized Iron.—Galvanized iron shall be 24 gage, of one of the following brands. ...., ..., or ....

Lead.—Lead used for sheet metal work shall be 6 pound rolled sheet lead.

Zinc.—Zinc used for sheet metal work shall be 11 gage rolled zinc of one of the following brands: ...., ..., or ....

Solder.—Solder shall be composed of one-half pig lead and one-half block tin (new metals) and shall conform to the specifications of the A.S.T.M., B-32.

3. Workmanship

Workmanship shall be first class in every respect and when complete all work shall be watertight.

4. Flashings

Flashing shall be provided at the intersection of the roof surface with all vertical surfaces, and around all openings. Unless otherwise shown, flashings shall consist of a base and counter, or cap flashing.

Where the design is such that the base and counter flashing method is impracticable, flashings shall be made continuous from the roof surface up and into the vertical surface.

Base Flashings.—In general, base flashings shall be 6 inches high and shall project 6 inches out on the roof.

Flashings shall be cut from as long sheets as possible so as to reduce the joints to a minimum. On sloping roofs the flashing sheets shall lap longitudinally, at least 3 inches.

On flat roofs the joints shall be flat locked and soldered.

Counter Flashings.—Counter flashings shall turn down over base flashings not less than 4 inches and shall be secured to the vertical surfaces. Against wood surfaces the counter flashing shall extend up under the exterior covering such as shingles, slate, weather-boards, etc., at least 2 inches above the butt of the second course, but in no case less than 4 inches above the roof and shall be nailed along the top edge about every 8 inches.

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[24] Adopted, Vol. 28. 1927, pp. 687, 1419.

At masonry walls the counter flashing shall extend 4 inches into the joints of the masonry. The sheets shall be bent to the required shapes and built in with the mason work. At concrete walls the counter-flashing shall be set in the forms before the concrete is poured.

Step Flashing.—Where sloping roofs intersect vertical surfaces the counter flashings shall be stepped up to follow the slope of the roof, with vertical lap joints. Longitudinal laps at joints shall be not less than 3 inches.

Flashings for Pipes.—All pipes passing through roofs shall be flashed and counter flashed with base flashing extending not less than 6 inches out on roofs. Base flashings shall be of sufficient length to cover the roofing course next below the pipe, and to extend up under the roofing course above as far as possible without puncture by nails.

Where pipes extend more than 12 inches above the roof, the counter flashing shall be caulked into the hubs or held with clamps embedded in elastic cement, and shall lap the base flashing not less than 4 inches.

Where pipes extend not more than 12 inches above the roof surface, the base flashing shall be carried up to within 1 inch of the top of the pipe, and counter flashed with a cap extending 4 inches over the base flashing and turned over and down into the pipe at least 2 inches. For small threaded pipe, the counter flashing shall consist of a threaded cap of such design as to enclose the base flashing.

Valley Flashings.—Open valleys shall be not less than 4 inches wide at the top and shall increase 1 inch in width for each 8 feet in length. Flashing pieces shall be in long lengths and shall be of sufficient width to cover the open portion of the valley and extend up under the roof covering not less than 6 inches on each side. The cross seams shall be locked and soldered. Edges of valley sheets shall be turned back ½ inch and held in place by cleats spaced not more than 12 inches apart and nailed to the sheathing.

Special valleys in connection with saw tooth roofs shall be formed in accordance with the detail drawings.

Saddle Flashing.—Crickets or saddles formed back of chimneys and similar vertical surfaces, shall be covered with sheet metal which shall be made a part of the flashing.

Special Flashings.—Special flashings shall be provided around all guy anchors, flag poles, supports for signs, etc., in accordance with the detail drawings.

5. Gutters

Eave troughs or hanging gutters of the size and type shown shall be provided where called for on the drawings. They shall be in long lengths, joined by 1 inch lapped and soldered joints, properly sloped to outlets and provided with necessary slip joints to take care of expansion and contraction.

Eave troughs shall be supported on approved hangers, spaced sufficiently close together to prevent distortion, and shall be provided with end pieces, end caps, outlets and mitres as required.

Molded gutters of the size and designs shown shall be installed where shown on the drawings. They shall have a flange which shall extend up under the roofing at least 6 inches and shall be held in place by cleats, spaced not more than 24 inches apart.

The outer edge of the gutter shall be stiffened by a metal bar and provided with a drip. The gutter shall be tied back against the roof by heavy metal braces spaced sufficiently close together to prevent distortion.

Joints shall be lapped 1 inch and secured with rivets and soldered. Molded gutters shall be provided with outlet tubes soldered to the gutter and shall have necessary slip joints to provide for expansion.

Where indicated on the drawings, all box or built-in gutters shall be lined with sheet metal in accordance with the details.

Gutter linings shall fit loosely and the back edge shall extend up under the roofing at least 6 inches. Joints in gutter linings shall be double locked and soldered. The lining shall be secured to the gutter box by cleats. Outlets in box gutters shall be provided by turning the gutter lining down into the outlet tubes and securing it to the tube by soldered lap seams.

All outlets in gutters shall be provided with an approved heavy wire strainer.

NOTE.—Special precautions shall be taken to support zinc gutters by brackets at close intervals to guard against collapse or distortion.

6. Eave Strips and Gravel Stops

Gravel stops and eave strips shall be provided at the edges of all built-up roofs. They shall be formed of one piece of sheet metal, wide enough to extend back 3 inches on the roofing and down to completely cover edges of the sheathing and form a drip. For use on roofs covered with gravel or slag, they shall be provided with a raised bead along the outer edge, the full height of gravel coating. They shall be nailed on top of the roofing felts, embedded in pitch and covered with a layer of felt mopped with pitch.

7. Cornices

Cornices shall be erected where called for on the drawings. They shall be made in strict accordance with the profiles shown, with moldings true, sharp and straight, mitres and joints carefully fitted, angles and corners reinforced, and all joints neatly riveted and soldered together and made watertight. Detail drawings of cornice work shall be submitted for approval before starting work.

Cornices shall be securely and rigidly attached to the building.

8. Rain Conductors, or Leaders

Rain conductors of the shapes and sizes indicated shall be provided where shown on the drawings. They shall be held in position clear of the walls by ⅛ in. by 1½ in. metal straps, spaced about 6 feet apart and soldered to the conductors. The straps shall be fastened to the walls of the building by screws or expansion bolts. Rain conductors shall be in 10 foot lengths with joints lapped and soldered. Rain conductors which connect with underground drains shall terminate in a cast iron boot set by the plumber, with the joint neatly cemented.

Where rain conductors discharge onto the ground they shall terminate either in a cast iron boot, or a sheet metal elbow, as shown on the drawings.

9. Rain Conductor Heads

Conductor heads of the design shown shall be installed where indicated on the drawings. Bottoms of heads shall be soldered to the conductors. Each head shall be equipped with a heavy removable wire screen.

Where sheet metal heads are used in connection with built-up roofing, these shall be not less than 16 inches square with outlet and tube to fit in the rain conductors and with a raised bead around the outlet to act as a gravel stop. Heads of this type shall have the flange or collar built in with the roofing.

10. Ridge Rolls and Hip Capping

Where shown on the drawings in connection with slate and shingle roofs, sheet metal ridge rolls and hip capping shall be provided in accordance with the details.

The aprons shall be held down by screws set through washers. The heads of screws and washers shall be soldered.

11. Ventilators

Ventilators of the size and type shown shall be installed in the locations shown on the drawings, and properly flashed in with the roofing. The flashing sheet shall extend out over the roofing 6 inches on all sides and shall be connected to the base of the ventilator by a soldered lap seam.

12. Skylights

Where shown on the drawings, skylights of the size indicated and of approved design and manufacture, shall be built with curbs at least 10 inches above the roof. All sheet metal shall be reinforced for strength and stiffness with steel sections.

Sash bars and bearings for glass shall have condensation gutters leading to the outside of the skylight, with cross gutters under butt joints in glass. Skylights shall be made water and weather tight with joints interlocked, riveted and soldered and shall be flashed and counterflashed at curbs.

Skylights shall be designed to safely support a live load of 50 pounds per square foot in addition to the dead load without deflection. Detail drawings for skylights shall be submitted for approval before the work is started.

For glazing of skylights see Section 16, Article 24, of this specification (Painting and Glazing).

13. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 12-A

[25]STRUCTURAL STEEL AND IRON

GENERAL DESIGN

1. General

The Contractor shall furnish all labor, material, tools and equipment necessary to entirely complete the structural steel and iron work as herein specified and as called for on the drawings.

2. Design

The design of steel or iron work required will be indicated on the drawings furnished by the Company, and such details as are not shown on these drawings shall be detailed on the shop drawings.

In case the Contractor is required specifically to design the structural steel or iron work, he shall submit complete stress diagrams with statement of loads used in design, and the design shall be in accordance with these specifications, and established clearances.

3. Dimensions for Calculations of Stresses

The dimensions for calculation of stresses shall be as follows:

(a) Span Length

For trusses, girders and beams, the distance center to center of end bearings or from center to center of columns or supporting beams.

(b) Depth

For riveted trusses, distance between centers of gravity of chord sections.

For pin-connected trusses, distance center to center of chord pins.

4. Spacing of Members

Roof trusses, rafters, etc., preferably shall be so spaced that single shapes may be used as purlins. Structures shall be so designed as to avoid, as far as practicable, ambiguity in the determination of the stresses.

5. Loads

All structures shall be proportioned for the following loads:

(a) Dead load
(b) Live or superimposed load
(c) Lateral forces and longitudinal forces from moving loads
(d) Impact or dynamic effect of moving loads.

The dead load shall consist of the estimated weight of all partitions, permanent fixtures, mechanisms and permanent portions of the structure.

The live or superimposed load, lateral and longitudinal forces and impact will be specified by the Engineer for each case. (See appendix for typical loading.)

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[25] Adopted, Vol. 28, 1927, pp. 691, 1419; Vol. 29, 1928, pp. 928, 1441; Vol. 30, 1929, pp. 552, 1470.

The effect of any vibration or movement of machinery or equipment shall be specified for each case by the Engineer. (See appendix for typical loading.)

Where uniform live loads per square foot are used for the roof and floors of a building, the roof slabs, joists, beams, girders and columns supporting same and all floor slabs, joists and beams shall be designed for full dead and full live loads. All floor girders shall be designed for full dead and 85 per cent of live loads. All columns, walls and piers supporting floors shall be designed for full dead load and the percentage of the live load given in the following table:

Floor	*Number of Floors in Building*														
No.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
15	85														
14	80	85													
13	75	80	85												
12	70	75	80	85											
11	65	70	75	80	85										
10	60	65	70	75	80	85									
9	55	60	65	70	75	80	85								
8	50	55	60	65	70	75	80	85							
7	50	50	55	60	65	70	75	80	85						
6	50	50	50	55	60	65	70	75	80	85					
5	50	50	50	50	55	60	65	70	75	80	85				
4	50	50	50	50	50	55	60	65	70	75	80	85			
3	50	50	50	50	50	50	55	60	65	70	75	80	85		
2	50	50	50	50	50	50	50	55	60	65	70	75	80	85	
1	50	50	50	50	50	50	50	50	55	60	65	70	75	80	85

The percentage of live load on walls, piers and columns of buildings more than fifteen stories in height shall be taken in the same ratio as the above table.

The loads of special equipment, such as trucks, engines, cranes, machinery or other appliances, shall be included.

6. Unit Stresses

The several parts of structures shall be so proportioned that the unit stresses will not exceed the following, except as modified in cases of combined and secondary stresses as set forth hereinafter.

Structural Steel:	*Pounds Per Square Inch*
Axial tension, net section	18,000
Axial compression, gross section	18,000-60 *l/r*
but not to exceed	15,000
l=the length of the member in inches	
r=the least radius of gyration of the member in inches.	
Tension in extreme fibers of rolled shapes, built sections and girders, net section	18,000
Tension in extreme fibers of pins	27,000
Shear in plate girder webs, gross section	12,000
Shear in power driven rivets and pins and turned bolts in reamed holes	13,500

Structural Steel:	*Pounds Per Square Inch*
Shear in hand driven rivets and unfinished bolts	10,000
Bearing of outstanding legs of stiffener angles and similar steel parts in contact	27,000
Bearing on power driven rivets, pins, turned bolts in reamed holes,	
(single shear)	24,000
(double shear)	30,000
Bearing on hand driven rivets, countersunk rivets and unfinished bolts,	
(single shear)	16,000
(double shear)	20,000
Bearing on expansion rollers, per linear inch	600d

d=the diameter of the rollers in inches.

For cast steel in shoes and bearings, the above mentioned stresses shall apply.

Note.—Rivets driven by pneumatically or electrically operated hammers are considered power driven.

Cast Iron:	
Axial tension, net section	3,000
Axial compression, gross section	12,000
Tension, extreme fiber in bending, net section	5,000
Compression, extreme fiber in bending, gross section	12,000
Shear	3,000
Axial compression, columns, gross section	$12{,}000-60\ l/r$
with a maximum of	10,000

l=the length of the member in inches

r=the least radius of gyration of the member in inches.

Bearing on Masonry:	
Brickwork	200
Rubble masonry	100
Granite ashlar	600
Sandstone or limestone (ashlar or capstone)	400
Concrete	500

The above unit stresses are based on masonry which shall comply with the standard specifications as set forth in other sections of these specifications for railway buildings.

PROPORTIONING OF PARTS

7. Slenderness Ratios

The ratio of length to least radius of gyration shall not exceed:

120	for main compression members of structural steel
100	for cast iron columns
200	for wind and sway bracing of structural steel
300	for riveted tension members

8. Depth Ratios

The depth of rolled beams in floors shall be not less than one twenty-fourth of the span. Where floors are subject to shocks or vibrations, the depth of beams and girders preferably shall be not less than one-twentieth of the span, or, if members of less depth are used, the sectional area shall be increased until the maximum deflection will not be greater than that of a beam with depth of one-twentieth of the span. The depth of roof purlins preferably shall be not less than one-twenty-fourth of the span, and in no case less than one-thirtieth of the span. Beams and girders supporting plastered ceilings, shall be so proportioned that the maximum deflection will not exceed 1/360 of the span.

9. Effective Bearing Area

The effective bearing area of a pin, bolt or rivet shall be its diameter multiplied by the thickness of the piece, except that for countersunk rivets half the depth of the countersink shall be omitted.

10. Effective Diameter of Rivets

In proportioning rivets, the nominal diameter of the rivet shall be used.

11. Net Section

In proportioning tension members, net section shall be used. Rivet holes deducted shall be taken one-eighth inch larger than the nominal diameter of rivets. The areas of rods shall be figured at the root of thread, or the rods upset at ends to provide proper net area.

12. Combined Stresses

Members subject to both axial and bending stresses shall be so proportioned that the combined fiber stresses will not exceed the allowable unit stress.

Members subject to stresses produced by a combination of dead load, live load and impact with lateral or longitudinal forces, may be proportioned for unit stresses 33⅓ per cent greater than those specified in Article 6, but the section shall be not less than that required for dead load, live load and impact.

13. Secondary Stress

Designing and detailing shall be done so as to avoid secondary stresses as far as possible. When secondary stresses are unavoidable, the unit stresses specified in Article 6 may be increased one-third for a combination of the secondary stresses with the other stresses but the section shall be not less than that required when secondary stresses are not considered.

14. Minimum Sizes

On inside work, metal less than one-quarter of an inch thick shall not be used except for fillers. On outside work and inside of engine houses metal less than $\frac{5}{16}$ inch thick shall not be used except for fillers. Webs of girders shall be not less than $\frac{5}{16}$ inch thick. Sole plates or bed plates shall be not less than ½ inch thick. Anchor bolts preferably shall be not less than 1 inch in diameter.

15. Corrosion

Metal subject to marked corrosive influence shall be increased in thickness or protected against such influence.

16. Expansion

No provision for expansion in structures transversely shall be made in wall bearing spans 50 feet and under in length. Wall bearing spans over 50 feet and up to and including 100 feet in length shall slide on smooth surfaces at one end. Wall bearing spans over 100 feet in length shall have expansion rollers or rockers at one end. Expansion rollers shall be not less than three inches (3") in diameter. Expansion ends shall be secured against lateral movement and all fixed ends against movement in any direction.

Provision shall be made for expansion in structures longitudinally. All expansion provisions shall be figured for 100 degrees Fahr. variation in temperature and for a co-efficient of expansion of 0.0000065 per degree per unit of length.

Trusses

17. Design

Trusses preferably shall be riveted structures. If, for special reasons, pin connected trusses are required, the design and details shall be in accordance with the requirements for design of such trusses specified in the A.R.E.A. Specifications for Steel Railway Bridges, third Edition 1925, or current revision thereof, except that the unit stresses of Article 6 and loads of Article 5 of this specification shall be used.

18. Camber

Trusses shall have sufficient camber so that the lower chord will be level under dead load only.

19. Compression Members

In built compression members of the open box type, the metal shall be concentrated in the webs and flanges. The thickness of each web shall be not less than one-thirtieth of the distances between the lines of rivets connecting it to the flanges. The thickness of cover plates shall be not less than one-fortieth of the distance between the nearest rivet lines.

20. Outstanding Legs of Angles

The width of the outstanding legs of angles in compression (except where reinforced) shall not exceed twelve times the thickness for main members or fourteen times the thickness for bracing and other secondary members.

21. Bracing

Lateral, longitudinal and transverse bracing in all structures preferably shall be composed of rolled shapes with riveted connections, and shall be designed to withstand wind and other lateral forces when the building is in process of erection, as well as after completion. Stresses from bracing preferably shall be carried directly to the foundation. Bracing connections to trusses shall be designed to avoid as far as practicable, any bending stress in the truss members.

Plate Girders and Rolled Beams

22. Design

Plate girders shall be proportioned by the moment of inertia of their net section, including compression side.

23. Flange Sections

The flange angles shall form as large a part of the area of the flange as practicable. Side plates shall not be used except when flange angles exceeding one inch in thickness otherwise would be required.

Flange cover plates shall be equal in thickness or diminish from the flange angles outward. No cover plate shall exceed the flange angles in thickness. Flange plates shall be limited in width so they will not extend more than eight times the thickness of thinnest plate, or a maximum of 6 inches beyond the outer line of rivets connecting them to the angles.

Where flange cover plates are used they shall extend 18 inches beyond the theoretical end.

24. Compression Flanges

The gross area of the compression flanges of plate girders shall be not less than the gross area of the tension flanges. The compression flanges of all built or rolled beams and girders shall be stayed against lateral buckling at intervals not exceeding thirty times the width of the flange. The flange stress shall not exceed 18,000—200 l/b where

l=the length of the member in inches between lateral connections or knee braces

b=the flange width in inches.

25. Flange Rivets

The flanges of plate girders shall be connected to the web with a sufficient number of rivets to transfer to the flange sections the horizontal shear at any point combined with any load that is applied directly on the flange.

26. Thickness of Web Plates

The thickness of web plates shall be not less than $\frac{1}{20}\sqrt{D}$ where D represents the distance between flanges in inches.

27. Stiffeners

Plate girders shall have stiffener angles over bearings, the outstanding legs of which shall extend as nearly as practicable to the outer edge of the flange angles. These stiffeners shall be proportioned for bearing of the outstanding legs on the flange angles, and shall be connected to the web by enough rivets to transmit the reaction. End stiffeners shall not be crimped.

28. Intermediate Stiffeners

Intermediate stiffeners shall be riveted in pairs to the webs of plate girders in which the thickness of the web is less than 1/60 of the distance between the flange angles or side plates. The outstanding leg of each angle shall not be more than sixteen times the thickness, nor less than 2 inches plus one-thirtieth of the depth of the girder. Pairs of stiffeners shall be placed at intervals not greater than the depth of the web, or 6 feet.

Stiffener angles shall be placed at points of concentrated loading. Such angles shall not be crimped.

Columns

29. Design

Columns shall be designed to provide for effective connection of beams, girders and brackets. Steel columns shall be designed preferably in two story lengths. Cast iron columns shall not be used in buildings of a height greater than two stories above the ground.

30. Eccentric Loading

In proportioning columns, provision shall be made for eccentric loading.

DETAILS OF DESIGN

31. Parts Accessible

Details shall be so designed that all parts will be accessible for inspection, cleaning and painting. Closed sections shall be avoided wherever possible.

32. Pockets

Pockets or depressions which would hold water shall be avoided.

33. Adjustable Members

Adjustable members in any part of the structure shall be avoided wherever possible. When used, adjustable members shall have open turnbuckles or clevises.

34. Symmetrical Sections

Sections shall be made symmetrical wherever practicable. The effective area of single angles in tension shall be assumed as the net area of the connected leg plus 50 per cent of the area of the unconnected leg. Single angles connected by lug angles shall be considered as connected by one leg.

35. Eccentric Connections

Eccentric connections shall be generally avoided, but if unavoidable, the members shall be so proportioned that the combined fiber stress will not exceed the allowed axial stress.

36. Spacing of Rivets

The minimum distance between centers of rivet holes shall be three diameters of the rivet, but the distance preferably shall be not less than 3½ inches for 1 inch rivets, 3 inches for ⅞ inch rivets, 2½ inches for ¾ inch rivets, 2 inches for ⅝ inch rivets and 1¾ inches for ½ inch rivets. The maximum pitch in the line of stress for compression members composed of plates and shapes shall not exceed sixteen times the thickness of the thinnest outside plate, or twenty times the thickness of the thinnest enclosed plate with a maximum of 12 inches. For angles with two gage lines with rivets staggered, the maximum pitch in each gage line shall not exceed twenty-four times the thickness of the thinnest plate with a maximum of 18 inches. If two or more web plates are used in contact, stitch rivets shall be provided to make them act in unison. In compression members the stitch rivets shall be spaced not more than sixteen times the thickness of the thinnest plate in the line of stress, and not more than thirty times the thickness of the thinnest plate in the direction at right angles to the line of stress. In tension members, the stitch rivets shall be spaced not more than twenty-four times the thickness of the thinnest plate in either direction. In tension members, composed of two angles in contact, a pitch of 36 inches may be used, and in similar compression members 20 inches, but the *l/r* ratio for each angle between rivets shall be not more than three-fourths of that for the member as a whole.

The pitch of rivets at the ends of built compression members shall not exceed four diameters of the rivet for a distance equal to one and one-half times the maximum width of the member.

37. Long Rivets

Rivets which carry calculated stress and whose grip exceeds four and one-half diameters, shall be increased in number one per cent for each additional 1/16 inch grip. If the grip exceeds six times the diameter of the rivet, specially designed rivets shall be used.

38. Edge Distance

The minimum distance from the center of any rivet hole to a rolled or sheared edge shall be:

Size of Rivet	*To Sheared Edge*	*To Rolled Edge*
1″	1¾″	1½″
⅞″	1½″	1¼″
¾″	1¼″	1⅛″
⅝″	1⅛″	1″
½″	1″	⅞″

The maximum distance from any edge to the nearest line of rivets shall be eight times the thickness of the plate but shall not exceed 6 inches.

39. Connections

Connections shall be made as nearly as practicable, symmetrical about the axis of the members. Wherever possible beams shall frame into girders and girders into columns and be connected to them with connection angles.

Connections carrying calculated stress, except for lacing, shall have not less than two rivets, or for field connections not less than three rivets. Connections of main members carrying live loads producing impact, and connections of members subject to alternate stresses shall be riveted. Turned bolts may be used in other connections where it is impracticable to obtain satisfactory power-driven rivets. The turned body of the bolt shall be long enough to insure full bearing. A washer at least ¼ inch thick shall be used under the nuts to give full grip when turned tight. When permitted by the Engineer, unfinished bolts may be used for the connections of minor parts.

40. Lacing and Stay Plates

The open sides of compression members shall be provided with lacing bars proportioned to resist a shearing stress of 2½ per cent of the direct stress. They shall have stay plates as near each end as practicable and at intermediate points where the lacing is interrupted. In main members the length of the end stay plates shall be not less than one and one-fourth times the distance between the lines of rivets connecting them to the outer flanges, and the length of intermediate stay plates shall be not less than three-quarters of that distance. Their thickness shall be not less than one-fiftieth of the same distance.

The minimum thickness of lacing bars shall be for single lacing one-fortieth and for double lacing, riveted at intersections, one-fiftieth of the distance between the end rivets. Their minimum width shall be as follows:

For 15 inch channels or built sections with 3½ and 4 inch angles	2½ inches	(⅞" rivets)
For 12, 10 and 8 inch channels or built sections with 3 inch angles	2¼ inches	(¾" rivets)
For 8 and 7 inch channels or built sections with 2½ inch angles	2 inches	(⅝" rivets)
For 6 and 5 inch channels or built sections with 2 inch angles	1¾ inches	(½" rivets)

The angle of lacing bars with the axis of the member shall be not less than 45 degrees. If the distance between rivet lines in the flanges is more than 15 inches, the lacing shall be double and riveted at the intersections, or shall be made of angles. Lacing bars of compression members shall be so spaced that the *l/r* ratio of the portion of the flange between their connections shall be not greater than three-quarters of the *l/r* of the member as a whole.

41. Splices

Abutting joints in compression members faced for bearing shall be spliced sufficiently to hold the connecting members accurately in place. Other joints in riveted work, whether in tension or compression, shall be fully spliced.

42. Web Splices

Web plates of plate girders shall be spliced symmetrically by plates on each side. The splice plates (for shear) shall be of the full depth of the girders between flanges. The splice shall be equal to the web in strength in both shear and moment. There shall be not less than two rows of rivets on each side of the joint.

43. Flange Splices

Two members of the same flange shall not be spliced at the same cross-section and if practicable, splices shall be located at points where there is an excess of section. The net section of the splice shall exceed by ten per cent the net section of the member spliced. Flange angle splices shall consist of two angles, one on each side.

44. Fillers

Where rivets carrying stress pass through fillers, the filler shall be extended beyond the connected member and the extension secured by additional rivets sufficient to develop the filler.

45. Separators

Where two or more rolled beams are used to form a girder they shall be connected by bolts and separators at intervals of not more than 5 ft. All beams having a depth of 12 inches or more shall have at least two bolts to each separator. When concentrated loads are carried from one beam to the other, or distributed between the beams, rolled or built-up diaphragms shall be used, designed with sufficient stiffness to distribute the load. Where beams are exposed they shall be filled with concrete or spaced sufficiently far apart to permit cleaning and painting.

46. Column Bases

Column bases shall be designed to distribute the column load on the footings.

47. Fixed Bearings

Bearings and ends of girders and trusses shall be secured against lateral movement.

MATERIALS

48. Specifications

Structural steel is to be in accordance with specifications of the American Society for Testing Materials, Specificaton A-9-21, or subsequent revisions thereof, which is the specification for structural steel in buildings, with the exception that Article 1 shall read as follows:

"Structural steel shall be made by the open-hearth process."

In Article 2, the reference to Bessemer steel shall be omitted.

Cast steel is to be in accordance with specifications of the American Society for Testing Materials, Specification A-7-24, Class B, or subsequent revisions thereof.

Cast iron is to be in accordance with specifications of the American Society for Testing Materials, Specification A-48-18, or subsequent revisions thereof.

WORKMANSHIP

49. General

The workmanship and finish shall be equal to the best general practice in modern structural shops. Material at the shops shall be kept clean and protected from the weather as far as practicable.

50. Straightening Material

Rolled material, before being laid off or worked, must be straight. If straightening or flattening is necessary, it shall be done by methods that will not injure the material. Sharp kinks and bends may be cause for rejection.

51. Finish

Shearing and chipping shall be neatly and accurately done and all portions of the work exposed to view shall be neatly finished. Outside burrs shall be removed with a tool making a $\frac{1}{16}$ inch fillet.

52. Punching

Holes in material whose thickness is not greater than the diameter of the rivets plus $\frac{1}{8}$ inch, may be punched full size. Holes in material of greater thickness shall be drilled or sub-punched and reamed.

53. Punched Holes

Punched holes shall be $\frac{1}{16}$ inch larger than the nominal diameter of the rivets. The diameter of the die shall not exceed the diameter of the punch by more than $\frac{3}{32}$ inch. If any holes must be enlarged to admit the rivets, they shall be reamed. Holes must be clean cut, without torn or ragged edges. Poor matching of holes may be cause for rejection.

54. Sub-Punched and Reamed Holes

In sub-punched and reamed work the holes for rivets $\frac{7}{8}$ inch in diameter or larger shall be punched $\frac{3}{16}$ inch smaller and, after assembling, reamed $\frac{1}{16}$ inch larger than the nominal diameter of the rivet. When rivets are $\frac{3}{4}$ inch or less in diameter, the holes shall be punched $\frac{1}{8}$ inch smaller and, after assembling, reamed $\frac{1}{16}$ inch larger than the nominal diameter of the rivet. The diameter of the die shall be not more than $\frac{3}{32}$ inch larger than the diameter of the punch.

55. Reamed Holes

Reamed holes shall be cylindrical, perpendicular to the member, and not more than $\frac{3}{32}$ inch larger than the nominal diameter of the rivets. Reamers preferably shall not be directed by hand.

56. Drilled Holes

Drilled holes shall be $\frac{1}{16}$ inch larger than the nominal size of the rivet. Burrs on the outside surfaces shall be removed.

57. Shop Assembling

The parts of riveted members shall be well pinned and thoroughly drawn together with bolts before riveting is commenced. The drifting done during assembling shall be only such as to bring the parts into position. Drifting to enlarge unfair holes will not be allowed.

58. Match Marking

Connecting parts assembled in the shop for the purpose of reaming or drilling holes in field connections shall be match marked, and a diagram showing such marks shall be furnished the Engineer.

59. Rivets

The size of rivets called for on the drawings shall be the size of the rivet before heating.

Rivet heads shall be of approved shape and of uniform size for the same diameter of rivet. Rivet heads shall be full, neatly made, concentric with the rivet shanks, and in full contact with the surface of the member.

60. Riveting

Rivets shall be heated uniformly to a light cherry red and driven while hot. Rivets when heated and ready for driving shall be free from slag, scale and carbon deposit. When driven they shall completely fill the holes. Loose, burned or otherwise defective rivets shall be replaced. In removing rivets, care shall be taken not to injure the adjacent metal, and if necessary, they shall be drilled out. Caulking or recupping will not be permitted.

Rivets shall be driven by direct acting riveters where practicable. The riveters shall retain the pressure after the upsetting is completed.

61. Field Rivets

Field rivets shall be furnished in excess of the nominal number required to the amount of fifteen per cent, plus ten rivets, for each size and length.

Field rivets shall be carefully selected and shall be free from fins or shoulders on the underside of the head.

62. Turned Bolts

Where turned bolts are used to transmit shear, the holes shall be reamed parallel and the bolts shall make a tight fit with the threads entirely outside of the holes. A washer not less than ¼ inch thick shall be used under each nut.

63. Screw Threads

Screw threads shall make close fits in the nuts and shall be U.S. standard.

64. Lacing Bars

The ends of lacing bars shall be neatly rounded unless otherwise called for.

65. Web Plates

The edges of web plates of girders which have no cover plates may be ⅛ inch above or below the backs of the top flange angles. Web plates of girders which have cover plates may be ½ inch less in width than the distance back to back of flange angles, but the web plates shall not extend beyond the backs of the flange angles, unless otherwise specified by the Engineer for each case.

When web plates are spliced, not more than ⅜ inch clearance between ends of plates will be allowed.

66. Abutting Joints

Abutting joints in compression members and girder flanges, and where so specified on the drawing, in tension members, shall be faced and brought to an even bearing. Where joints are not faced the opening shall not exceed ⅜ inch.

67. Finished Members

Finished members shall be true to line and free from twists, bends and open joints.

68. Welds

Steel shall be welded only with the approval of the Engineer.

69. Bearing Surfaces

The top and bottom surfaces of base and cap plates of columns and pedestals, except those in contact with masonry, shall be planed or hot-straightened, and parts of members in contact with them shall be faced to fit. Connection angles for base plates and cap plates shall be riveted to compression members before the members are faced.

Sole plates of plate girders shall have full contact with the girder flanges. Sole plates and masonry plates shall be planed or hot-straightened. Cast pedestals shall be planed on the surfaces in contact with steel and shall have the bottom surfaces resting on masonry rough finished.

70. Annealing

Wherever steel castings are used, they shall be properly annealed. Other steel, which has been partially heated, shall be annealed except where used in minor parts.

WEIGHING AND SHIPPING

71. Weight Paid For

The payment for pound price contracts shall be based on the scale weight of the metal in the fabricated structure, including field rivets shipped. The weight of the field paint and cement, if furnished, boxes and barrels used for packing and material used for staying or supporting members on cars, shall not be included.

72. Variation in Weights

If the weight of any member is more than 2½ per cent less than the computed weight, it may be cause for rejection.

The greatest allowable variation of the total scale weight of any structure from the weights computed from the approved shop drawings shall be 1½ per cent. Any weight in excess of 1½ per cent above the computed weight will not be paid for.

73. Computed Weight

The weight of steel shall be assumed at 0.2833-lb. per cubic inch.

The weights of rolled shapes and of plates, up to and including 36 inches in width, shall be computed on the basis of their nominal weights and dimensions as shown on the approved shop drawings, deducting for copes, cuts and open holes.

The weights of plates wider than 36 inches shall be computed on the basis of their dimensions, as shown on the approved shop drawings, deducting for cuts and open holes. To this shall be added one-half of the allowed percentages of overrun in weight given in specifications of the American Society for Testing Materials.

The weight of heads of shop driven rivets shall be included in the computed weight.

The weights of castings shall be computed from the dimensions shown on the approved shop drawings with an addition of 10 per cent for fillets and overruns.

74. Weights of Members

Finished work shall be weighed in the presence of the Inspector, if practicable. The Contractor shall furnish satisfactory scales and do the handling of the material for weighing.

75. Marking and Shipping

Members weighing more than five tons shall have the weight marked thereon. Bolts and rivets of one length and diameter, and loose nuts or washers of each size, shall be packed separately. Pins, other small parts, and small packages of bolts, rivets, washers and nuts shall be shipped in boxes, crates, kegs or barrels, but the gross weight of any package shall not exceed 300 lb. A list and description of the contained material shall be plainly marked on the outside of each package, box or crate.

Anchor bolts, washers and other anchorage or grillage materials shall be shipped in time for them to be built into the masonry.

SHOP PAINTING

76. Shop Cleaning and Painting

Unless otherwise specified, steel work, after it has been accepted by the inspector and before leaving the shop, shall be thoroughly cleaned and given one coat of approved paint, applied in a workmanlike manner and well worked into joints and open spaces. Cleaning shall be done with steel brushes, hammers, scrapers and chisels, or by other equally effective means. Oil, paraffin and grease shall be removed by wiping with benzine or gasoline. Loose dirt shall be brushed off with a dry bristle brush before the paint is applied.

77. Erection Marks

Erection marks shall be painted on painted surfaces.

78. Painting in Damp or Freezing Weather

Painting shall not be done in damp or freezing weather except under cover, and the steel must be free from moisture or frost when the paint is applied. Material painted under cover in damp or freezing weather shall be kept under cover until the paint is dry.

79. Mixing of Paint

Paint shall be thoroughly mixed before applying and the pigments shall be kept in suspension.

80. Machine Finished Surfaces

Machine finished surfaces of steel, except abutting joints and base plates, shall be coated with white lead and tallow, applied hot, as soon as the surfaces are finished and accepted by the inspector.

SHOP INSPECTION

81. Facilities for Inspection

Facilities for inspection of materials and workmanship in the shop shall be furnished by the Contractor to the inspectors, and the inspectors shall be allowed free access to the necessary parts of the premises in order to satisfy them that the material is being furnished and the work done in accordance with these specifications.

82. Material Orders and Shipping Statements

The Contractor shall furnish the Engineer with as many copies of material orders and shipping statements as the Engineer may direct. The weights of the individual members shall be shown.

83. Notice of Beginning Work

The Contractor shall give ample notice to the Engineer of the beginning of work at the shop, so that inspection may be provided. No work shall be done before the Engineer has been notified.

84. Cost of Inspection

The Contractor shall afford the Engineer free of cost all reasonable facilities to satisfy him that the material is being furnished and the work done in accordance with these specifications.

85. Inspector's Authority

The inspector shall have the power to reject materials or workmanship which do not meet the requirements of these specifications, but in case of dispute the Contractor may appeal to the Engineer, whose decision shall be final.

86. Rejections

The acceptance of any material or finished members by the inspector shall not be a bar to their subsequent rejection, if found defective.

Rejected material and workmanship shall be replaced promptly or made good by the Contractor.

ERECTION

87. General

The Contractor shall provide all tools, machinery, equipment and erection material, including drift pins and fitting up bolts, necessary for the expeditious handling of the work, and shall erect the structural steel and iron work complete in every respect as covered by the agreement and in accordance with the drawings and these specifications.

88. Drawings

Where the fabricated material is furnished by others, the Company will furnish complete detail drawings for the work, including shop details, erection diagrams, match marking diagrams, lists of field rivets and bolts, and copy of shipping statements.

89. Delivery of Material

The Contractor shall receive all materials entering into the finished structure free of charge at the place designated, loaded or unloaded as specified in the information given bidders.

90. Handling and Storage of Materials

The Contractor shall unload material promptly upon delivery, otherwise he shall be responsible for demurrage charges. Stored material shall be piled securely outside away from the tracks and no material shall be placed closer than 6 feet to the near rail. Material shall be placed on skids, above the ground. It shall be kept clean and properly drained. Girders and beams shall be placed upright and when necessary shall be shored. Long members, such as columns and chords, shall be supported on skids placed near enough together to prevent injury from deflection. The Contractor shall check all material turned over to him against shipping lists and report in writing at once any shortage or injury discovered. He will be held responsible for the loss of any material while in his care or for any damage resulting from his work.

91. Masonry

The Company will construct the masonry to correct lines and elevations and will establish the lines and elevations required by the Contractor for setting the steel.

92. Bearings and Anchorage

Bed plates, bolsters and shoes shall be set level in exact position. They shall be given full and even bearing by setting them on a layer of Portland cement mortar after blocking them accurately in position as directed by the Engineer.

The Contractor shall drill the holes and set the anchor bolts, except where the bolts are built into the masonry. The bolts shall be set accurately and fixed with Portland cement grout completely filling the holes.

93. Methods and Equipment

Before starting work the Contractor shall advise the Engineer fully as to the method he proposes to follow, and the amount and character of equipment he proposes to use, which shall be subject to the approval of the Engineer. The approval of the Engineer shall not be considered as relieving the Contractor of the responsibility for the safety of his method or equipment, or from carrying out the work in full accordance with drawings and specifications.

94. Erection

Structural steel and iron work shall be set accurately to the established lines and levels. The frame of steel skeleton buildings shall be carried up true and plumb. All parts shall be accurately assembled as shown on the drawings and match marks where shown upon the drawings or materials carefully followed. The material shall be carefully handled so that no parts will be bent, broken or otherwise damaged. Temporary bracing shall be provided to take care of stresses from erection equipment, piles of material or other loads carried during erection. As erection progresses, the work shall be securely bolted up to take care of all dead load, wind and erection stresses. Not less than one-third of the holes nor less than two holes at any connection shall be filled with bolts tightly drawn up. Light drifting will be permitted to draw parts together, but no drifting to match up unfair holes will be allowed; such holes shall be reamed or drilled. Bearing surfaces and surfaces to be in permanent contact shall be cleaned and painted just before the members are assembled. Elevator shafts shall be plumbed from top to bottom. The structure shall be accurately aligned and plumbed and splices and field connections drawn together with sufficient bolts to hold them securely in place before riveting.

95. Riveting

Riveting shall be done preferably with pneumatic riveters and buckers. Rivets larger than ⅞ inch in diameter shall not be driven by hand. Rivets shall be heated uniformly throughout to a light cherry red color, and in driving shall be upset to completely fill the holes. Heads shall be full and symmetrical and concentric with the shank, and shall have full bearing all around. They shall be of the same shape and size as the heads of the shop rivets. Rivets shall be tight and shall grip the connected parts securely together. No recupping or caulking will be permitted. Rivets shall not be overheated or burned. In removing rivets, the surrounding metal shall not be injured. If necessary, rivets shall be drilled out. Cup faced dollies, fitting the head closely to insure good bearing, shall be used.

Careless tossing of rivets will not be allowed. Rivets shall not be tossed in any direction that, if missed, they would fall outside of the working space adjacent to the building upon a public thoroughfare. The Contractor shall provide suitable shields to protect workmen from falling rivets.

96. Bolted Connections

Permanent bolted connections shall be used only where shown on drawings or where approved by the Engineer. In case bolted connections are used, washers not less than ¼ inch shall be used under the heads and nuts, the nuts drawn tight and the threads checked with a chisel or lock nuts used. Connections to cast iron and for separators in steel beams may be bolted.

97. Misfits

Any error in shop work which prevents the proper assembling and fitting up of parts shall immediately be reported to the inspector and his approval of the method of correction obtained.

98. Painting

The heads of field driven rivets shall be given a coat of paint similar to that used in the shop as soon as possible after the inspector has examined the rivets and found them satisfactory. All parts inaccessible after erection shall be painted before erection with one coat of field paint.

99. Superintendence and Workmen

During the entire progress of the work the Contractor shall have a competent foreman or superintendent in personal charge of the work. All work shall be done by skilled, competent workmen.

100. Interference with Traffic

When the work is adjacent to or over the tracks of the Company, the Contractor shall conduct his work in such a manner that the track shall be safe and clear for the passage of trains.

101. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all of the work is completed.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Appendix A

The following weights of materials, live loads and impacts are given as information for use in designing:

102. Weights of Materials of Construction

The unit weights of some materials will vary according to locality, and the weights of some will vary because of a difference in quality. The following values may be used as averages for ordinary conditions:

	Lb.
Book tile, 2 in. thick, per sq. ft	12
Book tile, 3 in. thick, per sq. ft	14
Beam tile (when not included with arch tile), per sq. ft	12
Brick masonry, pressed or paving, per cu. ft	140
Brick masonry, hard common, per cu. ft	120
Brick masonry, hollow, per cu. ft	90
Cast iron, bar 1 in. square, per linear ft	3.125
Cast iron, per cu. in	.26
Cinder concrete, per cu. ft	96
Cinder fill (without sand and cement), per cu. ft	72
Floors, marble, tutti colori, and similar, per sq. ft	12
Floor flat arch (average of set), 8 in. thick, per sq. ft	28
Floor flat arch (average of set), 10 in. thick, per sq. ft	32
Floor flat arch (average of set), 12 in. thick, per sq. ft	36
Floor flat arch (average of set), 14 in. thick, per sq. ft	40
Floor flat arch (average of set), 16 in. thick, per sq. ft	46
Floor segmental arch tile (average of set), 6 in. thick at crown, per sq. ft	28
Granite, per cu. ft	160
Gypsum partition blocks, 3 in. thick, per sq. ft	10
Gypsum partition blocks, 4 in. thick, per sq. ft	12
Gypsum partition blocks, 5 in. thick, per sq. ft	14
Gypsum partition blocks, 6 in., per sq. ft	16
Marble, per cu. ft	175
Mortar and plaster, per cu. ft	120
Mortar for tile arch floors, per sq. ft	3

	Lb.
Oaks, maple, per ft. board measure	5
Ornamental terra cotta, backed and filled with common brick, per cu. ft.	120
Partition tile, 3 in. thick, per sq. ft.	14
Partition tile, 4 in. thick, per sq. ft.	15
Partition tile, 6 in. thick, per sq. ft.	22
Partition tile, 8 in. thick, per sq. ft.	28
Partition tile, 10 in. thick, per sq. ft.	32
Plaster on brick, concrete, tile or gypsum, per sq. ft.	5
Plaster on lath, per sq. ft.	7
Roofing, composition, per sq. ft.	5
Roofing gravel, per sq. ft.	10
Roofing, slate, per sq. ft.	10
Roofing tile, per sq. ft.	10
Roofing, shingle, per sq. ft.	3
Sandstone or limestone rubble, per cu. ft.	140
Sandstone or limestone cut facing, per cu. ft.	150
Sheet metal roofing, cornice, etc., per sq. ft.	3
Suspended ceiling complete, per sq. ft.	10
Steel bar 1 in. square, per linear foot	3.4
Steel plate, 1 in. thick, per sq. ft.	40.8
Stone concrete, per cu. ft.	144
Windows (glass, frames and sash), per sq. ft.	5
White pine, spruce, hemlock, per ft. board measure	3
Yellow pine, fir, per ft. board measure	4

The following items may vary considerably in weight but the values given may be used for preliminary computations, or when the quantities are small:

	Lb.
Concrete stair construction, per sq. ft.	150
Iron stair construction, per sq. ft.	50
Partition, tile plastered, per sq. ft.	25
Same in hotels, per sq. ft. of floor	35
Same in office buildings, per sq. ft. of floor	25
Reinforcement of concrete, per cu. ft.	6
Sidewalk lights in concrete, per sq. ft.	30
Steel joists, per sq. ft. of floor	6
Steel girders, per sq. ft. of floor	4
Total weight of reinforced concrete, per cu. ft.	150
Wood stair construction, per sq. ft.	20

103. Live Loads

The following live loads may be followed in all cases except where they conflict with local building ordinances.

Structure	*Load in Lb. per Sq. Ft.*
Baggage rooms	150
Carpenter shops	150
Coaling platforms	special
Commissaries	300
Cotton loading platforms	200 to 400
Express buildings	150
File rooms	100 to 150; 100 lb. for cases spaced over 4'0" clear; balance 150 lb.
Fire escapes	100
Freight houses	300
Freight platforms	300
Garages	100
Hospitals	50

	Load in Lb. per Sq. Ft.
Hotels:	
Guests' rooms	50
Lobbies	100
Halls	100
Assembly rooms	100
Storerooms	150
Ice manufacturing plants	150
Ice crusher houses	150
Ice storage	special
Icing platforms	150
Laundries	100
Locker rooms	50
Machine shop	100
Mail rooms	100
Offices and office buildings	50
Paint shop	100
Passenger platforms	100
Planing mills	150
Power houses	100
Reading rooms	50
Residences	40
Restaurants	50
Roofs	25
Scale houses	50
Scrap docks	300
Sidewalks	100
Signal towers	60
Stables	100
Stairways (all)	100
Station foot bridges	100
Stock pens	100
Stock runways	100
Storehouses—	
Bananas—on racks	50
Cement	450
Cotton	250
Flour	300
Fruits	350
Glass	350
Grain	300
Groceries and canned goods	300
Hay—baled	225
Hay—loose	125
Hardware	300
Oil	250
Paint	250
Railway	300
Salt	300
Soda ash	200
Vegetables	350
Telegraph offices	50
Ticket offices	50
Tool equipment buildings	100
Trainmen's rooms	50
Transfer platforms	150
Waiting rooms	100
Wash rooms	50
Water treating plants	100
Wind pressure	15 and 20
Y. M. C. A. buildings	50

104. Special Loads

In addition to the live load which is assumed to be uniformly distributed over the floor, provision shall be made for any special loads such as elevators, machinery, water in tanks, coal in bins, space for storage of special materials, etc. The weight of water is 62.5 lb. per cubic foot, or 8 1/3 lb. per gallon; of bituminous coal, 50 lb. per cubic foot; of anthracite coal, 60 lb. per cubic foot.

The weights of elevators are usually given by the manufacturer for the particular situation.

105. Wind Load

Wind shall be assumed as acting horizontally from any direction and shall be provided for as follows:

(1) For Finished Structures: A pressure of 15 lb. per square foot on the sides and ends of the building, and on the vertical projection of roof surfaces.

(2) For Structures in Process of Construction: A pressure of 20 lb. per square foot on vertical surfaces and the vertical projection of inclined surfaces of all exposed framework.

106. Snow Load

Snow load shall be specified by the Engineer to suit local conditions. This load shall be considered a constant load on the horizontal projection of roofs from flat roof up to roof slope of 45 degrees, omitting snow load on roofs steeper than 45 degrees slope.

107. Lateral Force

The lateral force on crane runways to provide for the effect of crane trolleys shall be 20 per cent of the moving load of the crane. This load shall be applied at the top of rail of crane runway, one-half the load to each side of runway, and considered as acting in either direction normal to the runway rail.

108. Longitudinal Force

In the design of members supporting tracks for railroad engines for cars provision shall be made for a longitudinal force of 20 per cent of the live load, applied 6 feet above the top of rail.

In the design of crane runways provision shall be made for a longitudinal force per rail equal to 10 per cent of the wheel loads of the crane applied at top of rail on the runway.

109. Impact

Where live loads causing shock or vibrations are carried, the following shall be added to the computed live load stress produced by such loads to provide for the dynamic effect of impact:

Character of Load	*Impact Allowance*
Street cars, trucks and elevators	33% of live load stress
Traveling cranes	25% of live load stress
Stationary vibrating machines	10% of live load stress
Railroad locomotives or cars	33% of live load stress
Turbines	100% of live load stress

Appendix B

COMPARISON OF COLUMN FORMULÆ

Ratio l/r	*A.R.E.A. Bldg.* 18000-60 l/r	*A.R.E.A. Bridge* 15000-50 l/r	*Old A.R.E.A.* 16000-70 l/r	*Am. Br. Co. Specif.*	*Gordon* $\frac{12500}{1 - \frac{l^2}{36000r^2}}$
0	15000	12500	14000	13000	12500
5	15000	12500	14000	13000	12492
10	15000	12500	14000	13000	12465
15	15000	12500	14000	13000	12422
20	15000	12500	14000	13000	12363
25	15000	12500	14000	13000	12287
30	15000	12500	13900	13000	12195
35	15000	12500	13550	13000	12088
40	15000	12500	13200	13000	11968
45	15000	12500	12850	13000	11834
50	15000	12500	12500	13000	11688
55	14700	12250	12150	13000	11531
60	14400	12000	11800	13000	11364
65	14100	11750	11450	12500	11187
70	13800	11500	11100	12000	11002
75	13500	11250	10750	11500	10811
80	13200	11000	10400	11000	10313
85	12900	10750	10050	10500	10410
90	12600	10500	9700	10000	10204
95	12300	10250	9350	9500	9995
100	12000	10000	9000	9000	9784
105	11700	9750	8650	8500	9571
110	11400	9500	8300	8000	9356
115	11100	9250	7950	7500	9142
120	10800	9000	7600	7000	8929
125	10500	8750		6750	8717
130	10200	8500		6500	8507
135	9900	8250		6250	8299
140	9600	8000		6000	8094
145	9300	7750		5750	7892
150	9000	7500		5500	7692
155	8700	7250		5250	7495
160	8400	7000		5000	7305
165	8100	6750		4750	7118
170	7800	6500		4500	6934
175	7500	6250		4250	6754
180	7200	6000		4000	6579
185	6900	5750		3750	6408
190	6600	5500		3500	6242
195	6300	5250		3250	6080
200	6000	5000		3000	5921

Section 12-B

[26]ORNAMENTAL AND MISCELLANEOUS METAL WORK

(In preparation.)

Section 13

[27]CARPENTRY AND MILLWORK

1. General

Under the heading of "Carpentry and Millwork" shall be included all woodwork of every description, except lath, which forms a part of the completed building. The sizes of all timbers and lumber shall conform to the sizes shown on the drawings or specified hereinafter, and where sizes are not so indicated the Contractor shall request the Engineer to furnish this information before beginning the work affected. All lumber throughout the work shall be graded and classified in accordance with the American Railway Engineering Association "Specifications for Lumber and Timber to be used in the Construction and Maintenance of Way Departments of Railroads" and shall be subject to inspection as received at the site. Rejected lumber shall be promptly removed from the site by the Contractor.

2. Seasoning

All framing lumber and timbers shall be thoroughly air seasoned before being used, and all finishing lumber, flooring, ceiling, molded casing, base and window and door jamb shall be kiln dried. After delivery at the site all kiln dried lumber shall be protected from the weather and other damage until the final completion and acceptance of the building.

3. Species and Grades

The lumber used in the various parts of the work shall be of the species and conform to the grades listed below:

Description of Lumber	*Species*	*Grade*
Timbers and framing lumber	......	......
Window, transom and door frames	......	......
Exterior finishing lumber	......	......
Interior finishing lumber	......	......
Flooring	......	......
Ceiling	......	......
Moulded casings, base, window and door jambs	......	......
Roof and storm sheathing	......	......
Drop and bevel siding, weatherboards	......	......
Fencing	......	......
Shingles	......	......
Sash	......	......
Doors	......	......
Blinds	......	......

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[27] Adopted, Vol. 27, 1926, pp. 1129, 1421; Vol. 30, 1929, pp. 552, 1470.

4. Dressing

Unless otherwise shown on the drawings, all lumber used throughout the work shall be sized on four sides to uniform widths and thicknesses, except that sills may be rough and platform joists need be dressed on two edges only.

5. Treated Lumber

Where called for on the drawings, lumber treated with a preservative such as creosote oil or zinc chloride shall be used and such lumber shall be termed "Treated Lumber." Unless otherwise provided in this specification, the Railway Company will furnish all treated lumber, delivered on cars at the nearest available track to the building, and the Contractor shall provide for unloading, framing and erecting such lumber in his proposal, quality of workmanship to be the same as for other carpenter work under this specification. The Railway Company will furnish sufficient preservative and the Contractor shall apply two brush coats of this material to all parts of the lumber that have been framed. The preservative material shall be heated before application if directed by the Engineer.

6. Framing

All framing throughout shall be of the dimensions shown on the drawings and shall be placed as indicated. The framing shall be done in a neat, workmanlike manner to give close joints and shall be securely nailed, spiked and bolted. Studding shall be doubled at all openings and opposite each cross partition, and all corners and angles shall be made solid and well braced, and all bracket supporters tripled. All studs shall be in one piece from sill to plate. Horizontal block bridging of the same dimensions as the studding shall be inserted at intervals of four feet in height and at the level of all floors. Where partitions come over voids they shall be trussed as detailed, or according to instructions from the Engineer.

The Contractor shall provide and set all hangers, straps, shoes and bolts required in trussing partitions. Horizontal joist supports shall be carefully notched into studding and well nailed. Wall plates on top of studs shall generally be in two pieces, each of the same dimensions as the studding, breaking joints. All joints shall come over studs and not between studs.

7. Joists

Joists shall be of the dimensions shown on the drawings, and spaced as indicated. Through partitions carried from the ground floor up shall have a joist run close up against the same on either side at each floor. Joists carrying partitions, all trimmer joists, and all joists around wells or openings shall be doubled unless otherwise shown. Where their span is greater than 8 ft. joists shall be stiffened with bridging of the size shown crossed both ways between each joist, and placed at least every six feet. Ceiling joists shall be firmly spiked with the roof, and when not supported on intermediate partitions shall be in one piece.

8. Roof Framing

Roofs shall be framed and built in accordance with the detail drawings accurately fitted and securely nailed, spiked or bolted. Chords of trusses shall be in one piece unless otherwise detailed, and shall be set level and plumb and securely braced longitudinally and in the planes of the top chords. Trusses shall be framed with a camber as directed by the Engineer. Wall plate shall be in long lengths with lapped joints halved, and well spiked at all angles. Rafters and purlins shall be set at the centers shown on the drawings. They shall be carefully cut and set, and have a solid bearing over wall plates, beams, and at ridge pieces, and be well spiked at all bearings, and properly trimmed for chimneys or other openings. Sprocket or lookout pieces not less than 2 inches in thickness shall be carefully cut to form curves where shown, and well nailed to rafters. Sheathing boards shall be of uniform width, nailed twice at every bearing to avoid warping and injury to the roof covering; all joints to come on rafters.

9. Sheathing and Siding

Storm sheathing, when called for by the drawings, shall be laid diagonally or horizontally as detailed, and nailed twice at every bearing. Sheathing boards shall be of uniform width. Drop siding, shiplap and weather boards shall be placed truly horizontal, with tight square butt joints, closely and accurately fitted against all casings, sills, water table and corner boards. All siding shall be drawn tight, secret nailed if called for, and when complete shall be wind and rain proof.

10. Flooring

Rough flooring shall be of the dimensions shown on the drawings (tongued and grooved if called for), evenly laid, in long lengths and securely nailed throughout, all joints to come on joists. Finished flooring shall be dressed and matched, of the dimensions shown on the drawings, with not more than two joints together, and shall be secret nailed with wire or cut floor nails as directed by the Engineer. It shall be smoothed by hand or machine to the final finish. No floor board, except in closets, shall be less than four feet in length. Finished floors shall not be laid until the plastering is finished. Where maple flooring is called for as the finished flooring in warehouses and shops, it shall be of the dimensions shown but square edged and end matched, and unless otherwise directed shall be face nailed with wire floor nails.

Flooring shall be tightly driven up before nailing so that joints are absolutely tight. Where wood floors are laid over concrete sub-floors, a coat of approved liquid waterproofing compound shall be mopped over the concrete filling and screeds before the rough flooring is laid.

11. Building and Sheathing Papers, Etc.

Where called for on the drawings, storm sheathing and sub-flooring shall be covered with one layer of waterproof building paper, weighing not less than 5 lb. per 100 sq. ft. Paper shall be lapped at least two inches at all joints, and carried underneath all corner boards, casing, etc., making a windtight finish throughout.

12. Furring and Grounds

Interior surfaces of stone, brick or concrete walls which are to be plastered, also all studded partitions and ceilings where studs or joists are more than sixteen inches on centers, shall be furred with one by two inch furring strips placed sixteen inches on centers and securely nailed. Furring on masonry walls shall provide a plumb surface for lathing, and shall be nailed to wood bricks or inserts built into the walls by the mason. Grounds ¾ inch thick shall be provided around all openings and along base, and shall be in true planes.

13. Window and Door Frames

Window and door frames shall be substantially built to details, of kiln dried lumber, all securely framed into sills and heads. Frames shall be given one priming coat of paint before delivery at the site, and shall be braced and protected until the building is completed. Frames shall be set plumb and true, and shall be anchored into masonry walls by wrought iron ties attached to the frames with screws; and if in wood walls, shall be firmly fixed into reveals with wood blocks built in. Frames with transoms and mullions shall be made in one frame with transom bar and mullion mortised in. All frames shall be of proper size to receive sash and doors, and shall be weatherproof. Frames for double hung windows shall have sash pulleys built in as specified under "Hardware."

Where called for on the drawings, window frames shall be built to receive "winter" or "storm" sashes, and door frames to receive "storm" doors. Frames shall be built to receive screens where required. Plank frames for masonry walls shall have a break strip built into wall and nailed to frame around head and jambs.

14. Stairs

Stairs shall be strongly and rigidly built in locations shown, and as detailed. Rough work for all stairs shall be self-supporting without the aid of angle posts. Treads shall have molded nosings, be plowed into risers, and risers into the under side of treads, and both housed into the wall stringer and tightly wedged and glued. In general for all stairways, treads shall be 1¼ inch thick and risers one inch thick, and both of hardwood and shall be in one piece. All newels, balusters and handrails shall be as detailed. Landings and platforms shall be finished to match treads, and all finish on stairways shall match general finish throughout the building. Cellar and porch stairs on minor buildings may be open without risers where directed by the Engineer. Outside steps shall be framed with proper waterfall.

15. Outside Finish and Trim

Outside trim and finish shall be neatly and accurately fitted. All necessary base boards, water table, corner trim, casings, facias, frieze boards, cornice and mouldings, and everything necessary to make a complete, finished piece of work shall be furnished and erected.

16. Platform Shelters

Where platform shelter sheds have wood posts supported on concrete foundations, the posts shall be set in and bolted to a cast iron base which shall be securely anchored to the foundation. If treated wood posts are called for these shall be set in the ground and anchored and braced as detailed. Corners of posts, brackets and purlins shall be stop chamfered, and posts up to a height of 5 feet above the top of platform shall have the corners protected by steel angles. All braces and brackets shall be securely bolted, using beveled washers under bolt heads and nuts where required. Brackets for overhanging roofs shall be built as detailed and in locations shown, and shall be securely bolted to walls and set true against solid bearings. Where no ceiling is used on the under side of sheds and shelters, the roof sheathing shall be tongued and grooved, and of size and design shown on drawings. All necessary facia boards and moulds shall be provided, and ends of show rafters shall have scroll cut ends.

17. Interior Finish

Interior trim, wainscoting, chair rail base, picture moldings, etc., shall be kiln dried and conform to the details, be neatly and accurately fitted and mitred joints and secret nailed with fine finishing nails. If face nailed, all nails shall be set for puttying. Interior finish shall be free from hammer marks and shall be hand dressed and sandpapered where required. No splicing of the window or door trim will be permitted, and joints of bases, chair rail and mouldings must be carefully matched.

18. Cabinets, Counters, Etc.

All cabinets, counters, drawers, lockers, shelving, etc., called for on the drawings, shall be provided in place and fitted up with all hardware as specified under that heading. All lumber for this work shall be kiln dried, and of same species and grade as interior finish. Cabinet work shall be done in an approved manner, securely nailed and glued, and all drawers and cabinet doors shall work easily and fit accurately. Tops of counters shall be accurately joined, hand dressed, scraped and sandpapered so that joints will not show. Shelving shall be securely and rigidly built in place, supported by necessary brackets and cleats.

19. Toilet Partitions

Where wood water closet partitions are called for on the drawings, they shall be provided by the Carpenter, together with all metal fittings and hardware, and also doors in accordance with the details. In general these partitions shall begin at a point 6 inches above the floor and extend to a point 6 feet above the floor, and may consist of either standard ceiling fitted into ploughed stiles and rails, or panelled sections supported and fastened by nickel plated toilet partition fittings.

20. Sash

Sash shall be accurately made to fill openings, dressed and sanded to a smooth finish, pinned and through tenoned with muntins, etc., as detailed. They shall be checked for glass and moulded and shall be properly hung, hinged or pivoted as required. Sash for exterior windows shall have small groove cut around sash to make a watertight fit. Double hung windows shall have the sash carefully balanced and counterweighted with cast iron or lead weights hung on approved sash cord or sash chains of proper strength. Sash shall be fitted so as to operate easily, but shall not be so loose as to rattle. Casement windows shall be made watertight by grooving the bottom rails and providing rebates at jambs, head and meeting stiles. Glass sizes, thicknesses, widths of rails and stiles will be shown on the drawings. Where glass sizes only are given, width of rails, stiles and muntins shall be in accordance with standard mill practice.

All glass and glazing shall conform to Section 16, Painting and Glazing, Articles 24 and 25.

21. Doors

Doors shall be of the sizes and types shown on the drawings, properly and neatly hung so as to fill openings, free from warp, and fully equipped with all hardware necessary for their operation. Sliding doors in warehouses and baggage rooms shall have suitable protection built to protect the doors when in an open position, shall have all necessary stops, shall be so hung that the doors cannot be lifted off the track from the outside, and shall be hung and fitted so that no lateral motion will exist. Heavy and special doors shall be built to details with frames mortised together, backing rigidly fastened, and fitted with sash where shown.

Unless metal doors are called for, fire doors shall in general be built of three thicknesses of tongued and grooved boards nailed together in opposite directions with core laid diagonally and covered on both sides and all edges with asbestos sheets covered with sheets of tin. Fire doors shall be hung to close automatically in accordance with the standard practice of the National Board of Fire Underwriters.

A special schedule of hinged doors, showing thicknesses, sizes, design, panelling, glazing, etc., will be furnished to supplement this specification where needed. In general all panelled doors shall be 1¾ inch thick, except interior doors in minor buildings, which may be 1⅜ inch thick, stiles and rails to be through tenoned and pinned and solidly glued up. Doors shall be hung with the proper size and number of butts to prevent sagging. Double acting doors and gates shall swing clear and fill openings. Hardwoods carpet strips or thresholds shall be provided for all doors unless otherwise shown on the drawings.

22. Shingles

Where called for on the drawings, roofs and exterior walls of buildings shall be covered with shingles of the species and grade herein specified. Unless otherwise provided, shingles shall be 4 in. by 16 in. in size, laid 4½ inches to the weather, thoroughly nailed with coated shingle nails. No split shingles or pieces shall be used. Shingles shall be laid in courses which are truly horizontal or parallel with eaves, all joints truly vertical or perpendicular to eaves, joints alternating with courses below. Shingles at eaves and base shall be started with double course projecting one inch below the sheathing. Valleys shall have shingles cut parallel to valleys, leaving flashing exposed not less than 12 inches, and hips shall have shingles worked into Boston hips unless otherwise provided. All necessary saddle boards on ridge cap shall be provided and when completed, shingled roofs shall be watertight.

23. Miscellaneous Carpentry

The Carpenter shall provide in place all miscellaneous woodwork not above specified, such as wood foundation blocks and posts, fencing, latticing, coal bins, walkways in attics, wood gutters, signs, notice boards, etc., and do all necessary cutting, fitting and patching and special framing necessary for the proper installation of work of other trades. Upon completion of the work, the Carpenter shall remove all temporary work, scrap lumber and debris, draw all projecting and temporary nails, and leave the work in a complete, finished and orderly condition.

24. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed, and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 14

[28]LATHING AND PLASTERING

1. General

Under this heading shall be included all metal furring and cross furring, all wood and metal lathing, all plain and ornamental plastering and all stucco work. The Contractor shall provide all scaffolding, tools, labor and materials, and everything necessary to complete the plastering and stucco work shown on the drawings or required to complete the building.

2. Metal Furring

The Contractor shall furnish and set all metal furring, cross furring, forms, anchors and ties for all suspended ceilings, cornices, coves, moldings, etc., called for on the drawings. Where ceilings are hung below the beams of floor or roof systems, they shall be formed on steel channels of sizes indicated and spaced as shown, and securely fastened by means of hangers to the floor or roof members. Hangers shall be flat iron of dimensions shown, securely bolted and clamped to the beams and channels. Ceilings shall be cross furred as noted with one inch angles, channels or tees spaced 12 inches on centers. Cross furring shall be secured by approved clips to furring channels and beams.

3. Metal Lathing

Metal lath shall be painted or galvanized expanded metal, No. 24 gage, painted or galvanized after expansion, and of a make approved by the Engineer. All metal lath shall be drawn tight over steel furring, studs or joists, lapped not less than 3 inches at all sides where joints occur, and laced together and to the furring at intervals not to exceed 6 inches with No. 18 galvanized soft wire. Ends of wire shall be well twisted and bent up beyond lower line of lath. Lathing shall be left in perfect condition to receive plaster—level, true and rigid.

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[28] Adopted, Vol. 27, 1926, pp. 1136, 1421.

4. Painting

All metal furring, cross furring, ties, hangers and clips shall be painted on all sides before erection with one coat of approved lead and oil paint.

5. Wood Lath

Wood lath shall be of cypress, white pine, spruce, fire or hemlock, No. 1 quality, and shall be well-seasoned and free from sap, bark and dead knots. Before putting up any lath the lather shall test and check all studding, furring and grounds to see that they are all true and properly prepared for his work. Lath shall be securely nailed at every bearing, using two nails at ends, and shall break joints every sixth course. No lath shall be set vertical to fill out corners and no lath shall extend beyond any corner or angle. Where laths cross a bearing over two inches in width a strip or lath shall be put under the laths so there will be a space back of the laths for the plaster to key. Laths over doors or other openings shall have as few vertical joints as possible and where practicable laths shall extend across such openings. Laths shall be spaced ⅜ inch apart for ordinary lime mortar and ¼ inch apart for patented or hard plasters. At the junction of all walls covered with wood lath and unfurred brick or tile walls, and at all angles in walls covered with wood lath, a strip of metal lath not less than 24 inches wide shall be securely fastened over the entire length of the joint or angle, lapping 12 inches on each side.

6. Corner Beads

Except where rounded corners are specifically indicated, all exposed vertical corners where plastering occurs shall be provided with metal corner beads, securely fastened in place.

7. Interior Plastering

In general all plastering on lathed surfaces shall consist of a scratch coat, a brown coat, and the finishing coat. On unfurred brick or tile surfaces the scratch coat will be omitted. Each coat shall be permitted to dry thoroughly before the next coat is applied. Before beginning his work the plasterer shall test and prove the lathing and grounds so that the finished plaster will be plumb, true, level and waveless. Plastering shall run up behind all sill aprons, wainscoting, etc., and shall extend behind all bases.

Stone, brick or terra cotta walls to be plastered and all wood lath shall be thoroughly drenched with water before applying the first coat of plaster.

In hot dry weather, especially if windy, all openings in the building shall be closed while plastering, to prevent too rapid drying. In winter the temperature in the rooms being plastered shall be kept above the freezing point while plastering and until the plaster has hardened.

The scratch coat shall be well rubbed in and troweled against brick and tile and into lathed surfaces so as to form a perfect bond, and shall be scored and scratched in both directions to form a key for the brown coat.

The brown coat shall be applied to the scratch coat and brought flush with the grounds, with all surfaces straight, true, plumb, level and waveless.

The finishing coat shall be applied to the brown coat and may be a sand float or white trowel finish as specifically designated. If a white trowel finish is called for, it shall be made of Keene's cement and lime putty troweled to a smooth hard finish free from trowel or brush marks.

The plasterer shall run all plaster moulds, cornices, coves, etc., in accordance with models or full-sized profiles; all angles to be carefully and accurately mitred. Run work shall be carefully and accurately formed from templates to form continuous, unbroken, level lines. Ornamental enrichments shall be firmly secured in place with plaster of Paris, white lead and galvanized wire nails.

Unless otherwise permitted by the Engineer, all plastering shall be done with "Patented" or hard wall plaster of a brand specifically approved by the Engineer and mixed and applied in accordance with the Manufacturer's directions. Plaster shall be delivered at the site in the original unbroken packages and stored in a dry place until used.

Lime putty used for plastering shall be made from first quality pure lump lime, screened and free from impurities, and shall be mixed at least two weeks before being used.

Sand for plastering shall be sharp and angular and free from dirt, oil, or impurities that will stain the plaster. It shall be screened, washed and dried.

8. Patching

The plasterer shall do all necessary patching of plaster after the other mechanics have finished their work and shall leave same complete and perfect in every respect.

9. Exterior Stucco Work

The work required under this heading comprises the stuccoing of all exterior wall surfaces, as shown on the drawings and hereinafter described. Fresh stucco shall be protected from the weather and no stucco in which cracks, pits, streaks, discolorations or other defects may occur will be accepted. Cement shall be Portland cement for the under coats and white Portland cement for the finish coat in accordance with specifications for Portland cement described in the section of these specifications covering "Concrete." Aggregate for the under coats shall be thoroughly clean sand, graded from fine to coarse grains with the coarse grains predominating, and shall be free from loam, salt, vegetable and other deleterious matter. Aggregate for the finish coat shall be thoroughly clean yellow gravel grit, marble or granite screenings, as directed by the Engineer. Hydrated lime and coloring compounds shall be first quality, of a brand acceptable to the Engineer. Hair shall be first quality long cattle or goat hair.

Mortar for the first and second coats shall be composed of one part Portland cement, three parts sand and one-tenth part of hydrated lime by volume with sufficient hair added to bond the mortar to the lath.

Mortar for the finishing coat shall be composed of one part white Portland cement, three parts of aggregate and one-tenth part by volume of hydrated lime. This coat shall be brought to the tone selected by the addition of dry coloring compound not exceeding ten (10%) per cent of the weight of the cement.

Mixing shall be done on a watertight platform, the different constituents thoroughly mixed dry to a uniform color, water then added to obtain the proper consistency, and the whole turned over until the mass is uniform in color and consistency. No retempered mortar shall be used and no more mortar shall be mixed than can be used in thirty minutes. The dry color in the finishing coat shall be carefully weighted or measured and thoroughly mixed with the sand. The cement and lime shall then be added and the entire mass thoroughly mixed by shoveling from one side of the platform to the other through a ¼-inch mesh screen, and when the batch is of uniform color, the water shall be added.

The stucco shall be applied in three coats, each coat not less than ¼-inch nor more than ⅜-inch in thickness, the whole finishing ⅞-inch thick beyond the normal masonry line or 1 inch thick over the furring strips. The plastering shall be carried on continuously in one general direction without allowing the mortar to dry at the edge. Where this is impossible the joints shall be made at a break, an opening, or other natural division of the surface. Stucco shall not be applied when the temperature is below freezing. Masonry surfaces shall be cleaned and wet before the first coat is applied and brick walls shall have the joints raked out about ½-inch. The first coat shall be applied under pressure so as to secure a perfect bond with the masonry wall or lathed surface. After the first coat has set, but before it has dried, the second coat shall be applied and floated to a true plane. The under coats shall be cross scratched and scored before the initial set has taken place and shall be thoroughly wetted before the succeeding coats are applied. The finishing coat shall be kept damp for at least four days, either by sprinkling after the mortar has hardened sufficiently to permit it or by hanging wet burlap over the surface.

After the second coat has set, but before it has dried, the finishing coat shall be applied and finished in accordance with one of the methods hereinafter specified as directed by the Engineer.

EXPOSED AGGREGATE (INTEGRAL METHOD).—The finishing coat shall be ⅜-inch thick and, within 24 hours after it has been troweled to an even surface, shall be scrubbed with a stiff brush until the aggregate has been uniformly exposed. Should the cement be too hard to be readily removed by water, a solution of one part muriatic acid to five parts of water may be used; but as soon as the aggregate has been exposed, particular care shall be taken to remove all trace of acid by spraying thoroughly with clean water from a hose.

SMOOTH TROWELED.—Finishing coat shall be smoothed with a metal trowel, with as little rubbing as possible.

STIPPLED.—Finishing coat shall be smoothed with a metal trowel, with as little rubbing as possible, and then shall be lightly patted with a brush of broom straw to give an even stippled surface.

SAND FLOATED.—Finishing coat, after being brought to a smooth, even surface, shall be rubbed in a circular motion with a wood float. This floating shall be done when mortar has partially set.

ROUGH CAST OR SPATTER DASH.—After the finishing coat has been brought to an even surface and before attaining its final set, it shall be uniformly coated with a mixture of one part *white* cement to two parts *white* sand, thrown forcibly against the wall in such a manner as will produce a rough surface of uniform texture.

Pebble Dash.—After the finishing coat has been brought to an even surface and before attaining its initial set, clean pebbles shall be forcibly thrown against the mortar and embedded therein. Pebbles shall vary in size from ¼ inch to ⅜ inch, shall be well wetted before being cast, and shall be uniformly distributed over the surface. They may be pressed into the mortar with a clean wooden paddle, but the surface shall not be otherwise disturbed.

Note.—The above surface finishes are alternatives. Under no circumstances should the stucco be worked after it has attained its initial set.

Samples of the surface finish shall be laid up well in advance of the work, and the approved sample shall be carefully preserved during the prosecution of the work and used as a standard.

10. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed, and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 15

[29]MARBLE AND TILE WORK

1. General

The Contractor shall furnish all labor, materials, tools, scaffolding and equipment, except as otherwise noted, necessary to entirely complete any or all classes of marble or tile work herein specified, according to the class of building, and as shown or implied on the drawings.

2. Description of Marble

All marble specified or shown on drawings shall be the best of their several kinds, carefully selected for color, marking and location in the work, and each piece shall be subject to the Engineer's approval or rejection.

Samples 8 by 12 inches in size of each kind of marble specified shall be submitted for the Engineer's approval. These samples shall be finished as specified for the work and there shall be separate samples for each finish.

The completed work shall be equal to the approved samples as to quality, color, markings and finish.

3. Thickness

All marble shall be thick enough to be amply strong for its size and location and no slabs shall be less than ⅞ inch in thickness.

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[29] Adopted, Vol. 27, 1926, pp. 1140, 1421; Vol. 30, 1929, pp. 552, 1470.

All returns of 8 inches or less projection shall be from stock of sufficient thickness to form solid angles without vertical joints, angle pieces may be cut with hand saw, provided the position of joints is not altered from that shown on drawings. All molded or ornamented members shall be from stock sufficiently thick to permit of the finished work being an exact reproduction of the models or drawings without flattening. Projecting angles throughout shall be slightly rounded to prevent the edges chipping.

4. Setting and Anchoring

All slabs shall be set free from backing surfaces using brick furring on vertical surfaces, and other approved materials elsewhere. All bearing edges shall be bedded solidly and continuously their entire length and no material other than pure plaster of Paris and pure non-staining Portland cement shall be used in setting. Each piece of marble throughout the entire work shall be securely fastened in place with brass or bronze dowels, clamps and tees, which must be provided and used in ample numbers to make a rigid and permanent job. No tees shall be fastened to the marble or walls by cement or plaster only, but each must fit into a properly drilled seat, shaped to retain the setting mortar.

In no case shall any metal fastening show on the exposed faces unless specially mentioned herein or shown on the drawings. Specially made metal fastenings shall be used where necessary, or as may be directed.

5. Finish

The finishes to be given marble are as follows:

(a) All floors and floor borders, stair treads, risers and landings and door saddles are to be honed.

(b) All marble, except as noted in (a) above, are to be highly polished.

6. Joints

All joints shall be close, showing only a hairline and each piece of marble shall be worked to absolutely perfect edges. The exposed surfaces of all marble shall be worked to true planes so that abutting edges cannot be felt. Any surface dressing necessary to obtain these results shall be continued the full length and width of the piece affected, so that the dressing cannot be felt or seen, and this shall include any dressing required after the marble is set in place.

7. Supports for Marble Work

The Marble Contractor shall provide and set all steel supports of every description required specially for the proper setting of his work. Wherever this special steel framing is supported on the framing furnished and set by others, the Contractor for the marble shall furnish to such other contractors, within a reasonable time, carefully prepared drawings showing all required framing connections in detail so that provision may be made for the proper construction of the work, without unnecessary cutting and drilling, but if such framing is already in place, the Contractor for the marble work shall do all cutting, fitting and drilling required to properly connect his work to such framing.

All steel supports furnished by this contractor shall be given three coats, one shop coat and two field coats, of approved paint.

8. Floors and Floor Borders

Wherever floors, floor borders or panel divisions are specified or shown they shall be not less than ⅞ inch in thickness, and at all openings shall be increased in width to meet the door saddles or filling pieces, which take the place of saddles.

9. Terrazzo (Monolithic)

Floors are to be divided into panels, as indicated on the drawings. Wherever shown borders of different colored terrazzo are to be run, and panels are to be formed by strips of colored terrazzo.

Floors shall be composed of Portland cement and selected first quality chips of marble. Chips shall be of a reasonably uniform size, perfectly clean and uniformly distributed over the surface, and showing the greatest possible proportion of marble in the finished state.

Wherever terrazzo base is indicated it shall be of the height required above the floor, finished with a one inch radius cove at the intersection with the floor.

The Contractor shall submit finished samples not less than six inches square showing the color and finish for the Engineer's approval before work is started.

10. Terrazzo (Tile)

All rooms so indicated on drawings shall have terrazzo tile floors and base as manufactured by.......................................or equal. The pressure used in the manufacture of all tile for the work shall not be less than 2,500 lb. to the square inch. All tile shall be 12 inches by 12 inches for the field and have a double border. All tile to be not less than one inch in thickness. All rooms having terrazzo tile floors shall have a 6-inch terrazzo cove base as detailed. All doors shall have terrazzo plinths in connection with terrazzo base. Tile must be so made that their structure will be free from air bubbles, and when rubbed to a finished surface must present a solid body. No tile, the surface of which has been filled or otherwise treated after rubbing, shall be used. The tile shall be laid in a true and level plane at elevations shown on drawings, in a first-class and workmanlike manner. Great care shall be taken to have all lines and spacings true and straight, and all joints of even width, not exceeding 1/16 inch. Terrazzo thresholds shall be provided at all doors in connection with terrazzo tile floors, unless threshold of other materials are called for.

Tile shall be set on a bed of mortar composed of two parts Portland cement and three parts sand. Tile to be rammed to a solid and even bed, grouted and rubbed.

Before depositing bedding mortar, the entire surface shall be cleaned and well saturated with water to prevent too rapid absorption of water from bedding mortar.

After tile is laid and properly grouted, all tile floors shall be holystoned to reduce inequalities of surface. All tile for floors and base shall be made with marble chips of kind and color selected by the Engineer. The Contractor shall submit samples of tile and setting plan for approval before getting out any work.

The Contractor shall guarantee all terrazzo work for a period of one year after completion against defects of workmanship or material.

11. Marble for Floors

Marble floors and floor borders shall be composed of marble tile not less than ⅞ inch in thickness, cut with full faces, sawn bed, and all edges rubbed to the exact size required.

Each piece of marble shall be set in full bed of Portland cement mortar, and when set, all joints shall butt and match perfectly and closely and shall be perfectly flush. All pieces shall be selected and located in the floor according to character of veinings and color.

12. Vitrified Tile

(a) ON WALLS.—Tile for walls shall be salt glazed white tile laid in cement with hair line joints absolutely plumb and true without waves. Where trim of other material is not specified, the tile shall be returned into all reveals and soffits and the angle shall be formed of angle tile with corner rounded to a radius of about one inch. Where tile wainscot is called for there will also be required a sanitary tile base 8 inches high.

(b) FLOOR TILE.—Floor tile shall be hexagonal or other approved shapes of vitrified tile, set in cement mortar. Border of 2 inch square tile shall be laid at the intersection of floor with base.

13. Beds

The distance from the finished floor to the rough floor shall be not less than 2 inches and this Contractor shall fill in on top of the rough floors to the desired line with concrete composed of one part Portland cement, two parts sand and four parts crushed stone or gravel to form bed for flooring material.

14. General Conditions.

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered as to apply with equal force to this section of the specification.

Section 16

[30]PAINTING AND GLAZING

1. General

Under the heading of "Painting" shall be included the following:

(a) Painting and finishing exterior and interior woodwork.
(b) Painting structural steel and iron work and all ornamental iron work.
(c) Painting exposed sheet metal work and rain conductors.
(d) Painting plastered surfaces.
(e) Painting brick and concrete wall surfaces and concrete ceilings.
(g) Painting and lettering signs, and lettering on doors, etc.
(h) Painting radiators, piping, etc.

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[30] Adopted, Vol. 27, 1926, pp. 1144, 1421; Vol. 30, 1929, pp. 552, 1470.

Under the heading of "glazing" shall be included the furnishing and setting of glass in window, door, transom and ceiling sash, including metal sash, and furnishing and setting glass in skylights and marquises.

The Contractor shall furnish all labor, tools, equipment and everything necessary to complete the painting and glazing required. The equipment shall include all ladders, scaffolding or staging necessary to execute the work. No ladders, scaffolding or staging shall be placed where they will interfere with the safe operation of trains and in buildings partially or wholly occupied by the Company and in which painting is in progress the Contractor shall take proper precautions to protect the public and employees of the Company from any and all damage from his operations.

2. Materials

Paints, stains and varnishes shall be of a brand acceptable to and approved by the Engineer, and shall be delivered at the site in the original unbroken factory containers with labels intact. Paints shall be furnished in ready mixed form and shall be thinned only in accordance with the directions furnished by the manufacturers or as directed by the Engineer. Thinners shall be pure raw linseed oil or pure spirits of turpentine or a mixture of these two. Benzine, naphtha, gasoline or coal oil will not be allowed on the work or mixed with any of the materials used. Paints not otherwise specified may consist of pure raw linseed oil and white lead, properly tinted, each coat to be of slightly different shade, and the final coat to be of a shade and color approved by the Engineer.

Enamels shall consist of long oil, easy flowing, durable varnishes, that remain white, set dust free in six hours and hard in twelve hours, capable of being rubbed in two days.

Interior wood stains shall be of pure color, with linseed oil vehicle, permanent as to shade, sharp and clear in tone and capable of deeply penetrating the surface.

Shingle stains shall be of a pure color with creosote or other wood preservative as the vehicle, and shall be permanent as to shade and deeply penetrating.

Varnishes shall be oil and gum goods that will withstand hard use and not show white or dust on the surface.

3. Application of Paint

Only careful and skilled workmen shall be employed and special care shall be taken to avoid spattering, or setting of pots where they will disfigure the finished work. Canvas and building papers shall be spread where directed by the Engineer in order to protect finished or unfinished work. Paint shall be kept thoroughly stirred while being applied.

4. Preparing the Surface

Woodwork shall be carefully hand-smoothed and nail holes, cracks or other imperfections of the surface shall be puttied after the priming coat is applied.

Paints, fillers, stains or varnishes must not be applied to wet, frosty or rusty surfaces, to wood showing sandpaper marks or to surfaces not properly prepared. Knots, pitch pockets or sap shall be completely coated with first quality pure orange shellac before any paint is applied. Castings shall be filled with an iron filler and smoothed with emery and all imperfections treated and faced before applying the first coat of paint.

Brick, concrete, and plastered surfaces shall be absolutely dry before any paint is applied. Such surfaces shall be thoroughly cleaned with brushes to remove any loose material. Concrete floor surfaces shall be absolutely dry and free from oil, grease, dust, loose particles or any foreign matter that will in any way interfere with the most perfect penetration of the paint into the pores of the surface.

5. Time for Drying

Each coat of paint shall be given sufficient time to dry hard before the next coat is applied.

6. Weather and Temperature

Exterior painting shall not be done during damp or freezing weather, and all fresh work shall be protected from damage. For interior work the temperature shall not be allowed to fall below 60 degrees Fahr., while paint is being applied or while it is drying.

7. Priming Coats

In general all exterior woodwork shall be given one priming coat of the same paint that is to be used for the finishing coats, thinned with pure spirits turpentine and pure raw linseed oil, as directed. This priming coat shall be applied as early as possible after such woodwork is erected, and well brushed into the pores of the wood.

Priming coats for window and door frames, structural steel and iron work, and the back of paneled wainscoting and partitions shall be applied in the shop before the wood or metal is subjected to dampness.

Priming of interior woodwork, plastered, concrete and brick surfaces will depend on the nature of the surfaces and the finishing coats to be used, as hereinafter specified.

8. Painting Exterior Wood Surfaces

All exterior wood surfaces of every description, unless otherwise noted, shall receive, in addition to the priming coat, two coats of lead and oil paint of approved brand and color. The third coat shall consist of the ready mixed paint as it comes from the container used without thinning.

Unless otherwise directed, exterior doors shall be painted three coats on both sides, except where interior woodwork is to be varnished, in which case the outside only will be painted and the inside finished as described in Article 11. Tops and bottoms of doors shall be painted three coats.

9. Finishing Interior Woodwork

Interior wood surfaces shall be finished by one of the following methods or by a combination of these methods, as may be designated or directed by the Engineer:

1. Painting with three coats of lead and oil paint.
2. Finishing in natural wood colors.
3. Staining and varnishing.
4. Enameling.

10. Painting Interior Wood Surfaces

Where interior wood surfaces are to be painted, such surfaces shall receive, in addition to the priming coat, two coats of an approved brand of lead and oil paint, using such colors as will conform to the Company's standard practice or as may be directed by the Engineer.

11. Staining and Varnishing Interior Wood Surfaces

Where interior wood surfaces are to be finished with varnish, the work shall be done as follows:

(a) Natural Finish:

1. (For Open Grain Woods, Such as Mahogany, Ash, Chestnut, Etc.):

The surface shall be sandpapered smooth and all nail holes stopped with putty, using putty colored to match the wood. Then apply one coat of paste filler and before the filler has hardened, rub off clean, rubbing across the grain. Allow the filler to harden 24 hours and sandpaper with fine sandpaper. Next apply one coat of orange or white shellac, depending on whether a dark or light finish is desired, and two coats of first quality interior varnish. At least 48 hours shall be allowed for drying between coats. The final finish shall be dull or polished, as directed by the Engineer. For a dull finish, rub with powdered pumice and water 72 hours after the final coat is applied.

2. For finishing close grained woods, such as pine, cypress, birch, maple, etc., use the method described for open grained woods with the omission of the paste filler.

(b) Stain and Varnish Finish:

1. (For Open Grain Woods).—After sandpapering the surface and puttying nail holes, apply one coat of oil stain wiped off, one coat of filler rubbed off, one coat of orange or white shellac, and two coats of first quality interior varnish. After filler has hardened 24 hours, sandpaper as described in paragraph (a) of this article, and finish final coat of varnish with either dull or gloss finish, as directed.

2. (For Close Grain Woods).—Apply one coat of approved oil stain, one coat of shellac and two coats of interior varnish, allowing each coat to dry before another is applied. Finish final coat of varnish with dull or gloss finish as directed.

12. Exterior Varnishing

Where exterior woodwork is to be finished with varnish, or with stains and varnish, first apply one light coat of a mixture of 25 per cent pure linseed oil and 75 per cent pure spirits of turpentine, allow to dry and sandpaper, and then follow the specifications as given in Article 11, except that exterior spar varnish shall be used and the coat of shellac omitted.

13. Enameled Finishes on Wood or Plastered Surfaces

Where enameled finishes are called for on wood or plastered surfaces, these surfaces shall be given three coats of flat white, each of which shall be lightly sandpapered before the succeeding coat is applied, and shall then be given two coats of approved enamel applied in accordance with the manufacturers' instructions.

14. Finishing Wood Floors

Wood floors shall be finished by one of the following methods as directed by the Engineer:

(a) Oiling with linseed oil (for woods such as maple or yellow pine).

Floors to be oiled shall be given three coats of linseed oil, heated as nearly as possible to the boiling point. Ample time for absorption shall be allowed between each coat, and the floor shall not be used until the third coat has thoroughly dried.

(b) Finishing with varnish (for woods such as yellow pine, oak, etc.).

Floors to be finished with varnish shall be given one coat of floor varnish, thinned by adding one pint of turpentine to each gallon of varnish, and two coats of first quality elastic floor varnish. The floor shall be lightly sandpapered with fine sandpaper after the first varnish coat is dry. Oak floors shall be given one coat of paste filler, rubbed off, before the first varnish coat is applied.

15. Painting Structural Steel and Iron Work

All structural steel and iron work, including pipe railings and castings, in addition to the shop priming coat specified in the section of these specifications covering "Structural Steel and Iron" shall be given two coats of the Company's standard exterior or interior paint as directed. Surfaces in contact or inaccessible after erection shall be given one field coat before assembly or erection.

16. Painting Sheet Metal Work

All sheet metal work (other than copper), including flashings, gutters, rain conductors, skylight frames, and metal roofs, shall be given three coats of an approved metal paint, of such colors as may be directed by the Engineer. Surfaces of tin or galvanized sheet metal work and iron and steel in connection therewith, shall be thoroughly cleaned of grease, oil and traces of soldering flux before any paint is applied. Surfaces that will be unexposed after being placed and the under side of metal roofing shall be given one coat of paint before being installed. Before the priming coat is applied to galvanized sheet metal work, the surfaces shall be washed with a weak solution of vinegar, or a solution of sal-soda and water, using one pound of soda to three gallons of clean water. This wash shall be allowed to dry 24 hours before the priming coat of paint is applied. Surfaces inaccessible after erection shall be given a priming coat and one other coat before being erected. Paint shall be applied with hand brushes and well rubbed in. No dipping will be permitted.

17. Painting Plastered Surfaces

After they are thoroughly dry, plastered walls and ceiling shall be given one coat of approved alkali-proof wall size and two coats of approved interior wall paint with the flat or eggshell finish, applied strictly in accordance with the manufacturer's directions. Each coat shall be allowed to dry not less than 24 hours before the next coat is applied.

18. Painting Brick and Concrete Walls

Interior brick and concrete wall surfaces, except in basements and engine houses, shall be given three coats of lead and oil flat wall paint of colors selected by the Engineer. Care shall be taken to see that these surfaces are free of all moisture before any paint is applied.

19. Painting Piping and Radiators

Exposed piping and radiators in waiting rooms, offices, living rooms, lavatories, etc., shall be given one priming coat and two finishing coats of paint of an approved brand and color. Surfaces subjected to heat, such as steam piping and radiators, shall be painted with heat-resisting paints.

Exposed piping in basements, shop buildings, etc., and concealed piping which is not to be covered shall be painted two coats.

Covered piping shall be given one coat of paint before the covering is applied, and the covering when in place shall be given two coats of paint of approved brand and color.

20. Painting Interior of Engine Houses

The interior walls, posts, etc., of frame engine houses and all wood framing and sheathing of all engine houses shall be given two coats of light colored fire-resisting paint. For a distance of 6 feet above the floor all walls, posts, etc., shall be given two coats of lead and oil paint of a dark color as selected by the Engineer.

All interior brick and concrete walls in engine houses shall be given one coat of light colored cold water paint or whitewash from a point six feet above the floor to the under side of the roof, and three coats of dark colored lead and oil paint from the floor to a height of 6 feet. Cold water paint must be carefully brushed in so that one application will entirely cover the masonry surfaces with an opaque coat.

21. Staining Shingles

All shingles on roofs and walls shall be dipped or given two brush coats of approved creosote shingle stain. The stains shall be kept thoroughly stirred and shall be applied without dilution or adulteration to the thoroughly dry shingles. In dipping all shingles shall be immersed butt end first to a depth of three-fourths the length of the shingle.

22. Sign Painting and Lettering

The Contractor shall paint all necessary names, letters and numbers on all doors, signs, notice boards, etc. Letters and numbers shall conform to the Company's standard as to size and style, and the work shall be done by skilled sign painters.

23. Samples of Painting

Before beginning any painting the Contractor shall submit on wood blocks for the approval of the Engineer two samples of every kind of finish, and the final finishes shall conform to the approved samples.

24. Glazing

The Contractor shall furnish and set all glass of every description for window, door, transom, and ceiling sash, including metal sash and all glass in skylights and marquises. Sash must be primed and thoroughly dry before any glass is set.

All putty, excepting for metal sash, shall be first quality white lead putty mixed with pure linseed oil.

Unless otherwise marked on the drawings glass for wood sash shall be American, double strength, Class "A."

Glass for main entrance doors shall be polished ¼ inch plate glass.

Glass for skylights, marques, metal sash and metal doors, unless otherwise specified or called for on the drawings, shall be ¼ inch factory ribbed wire glass.

Where opaque or figured glass is called for on the drawings, this shall be Florentine, Maze, or other "approved" figured glass.

Samples of all glass to be used shall be submitted to the Engineer for approval, and all glass to be used in the work must conform strictly in quality with the approved samples.

GLAZING IN METAL SASH.—Glass in metal sash and doors shall be bedded in litharge putty, then clips or stops applied, back puttied and neatly face puttied; finished surface of putty shall show absolutely smooth, true and free from sags or wrinkles.

GLAZING IN WOOD SASH.—Glass in wood sash shall be back puttied, securely fastened with glaziers' points and neatly face puttied.

GLAZING IN DOORS.—Glass in wood doors shall be fastened in place with removable wood stops.

GLAZING SKYLIGHTS AND MARQUISES.—Glass in skylights and marquises shall be secured in place by the use of copper strips and copper screws and shall be made watertight.

25. Final Cleaning

Before the building is tendered for final acceptance all broken glass shall be replaced, all glass of every description shall be thoroughly cleaned, and all paint stains removed from floors, walls, brickwork, marble and finished surfaces.

26. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 17

[31]HARDWARE

1. General

The Contractor shall provide and set all rough and finish hardware necessary for the operation of all doors, windows, blinds, screens, screen doors, toilet partition doors, cabinets, drawers, gates, ticket windows, etc., and for completely equipping the building. Hardware shall be neatly and accurately fixed in place by skilled mechanics, with screws or bolts, which shall match the hardware and shall be left in perfect working order, free from rust, scratches and other defects. The Contractor shall provide such hardware as screws, bolts, coat and hat hooks and other minor articles, although not specifically mentioned or shown, but necessary for the ordinary operation of the building. All hardware required in connection with slate or marble toilet partitions shall be furnished by the Plumbing Contractor. Hardware for toilet partition doors will be furnished and fitted to the marble or slate partitions by the Plumbing Contractor, but the doors will be hung by the Carpenter. Where wood toilet partitions are called for, all necessary hardware shall be furnished and set by the Carpenter and such hardware shall be included in this schedule. All escutcheons, push plates, kick plates, push bars, etc., shall be set after the wood finishing and varnishing are completed.

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[31] Adopted, Vol. 27, 1926, pp. 1150, 1421.

2. Finish Hardware

Finish hardware shall be selected by the Engineer. As a basis for bids the Contractor shall include in his proposal the sum of .... dollars ($.........) to cover the purchase cost of all finishing hardware, together with freight on same to the building. Any difference between actual cost and this sum will be added to or subtracted from the lump sum amount of the contract as the case may require. The cost of placing the finish hardware shall not be covered by the above amount, but shall be included by the Contractor in his proposal.

3. Rough Hardware

The Contractor shall furnish all rough hardware of every description and shall include the cost of furnishing and setting such hardware in his proposal. Rough hardware shall include nails, spikes, screws, bolts and washers, sash pulleys, sash weights, sash cord or chain, sliding door hardware, fire door hardware, special operating devices for rolling doors, horizontal cross folding doors and all windows requiring special operating devices. In general special hardware will be noted on the drawings or described in a supplement to this specification, but where not so shown and described it shall be furnished and placed if necessary for the operation and use of the building. Hardware for sliding doors shall include all track, hangers, bumpers, stops, stay rollers, chafe and binder strips, door pulls and locks.

Hardware for fire doors shall be of an automatic type approved by the National Board of Fire Underwriters.

Sash weights shall be of cast iron or lead and of proper weight to exactly counterbalance the sash, and shall be properly proportioned to fit in the weight boxes.

Sash pulleys shall be of an anti-friction type, of proper size and with approved face. Sash weights and pulleys shall be fitted to the sash and frames at the mill manufacturing same.

Hardware for special doors such as engine house doors, shall be of extra heavy design to prevent sagging of doors. All rough hardware shall be of substantial construction and of a make approved by the Engineer.

4. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed, and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 18

PLUMBING[32]

1. General

The Contractor shall furnish all labor, material, tools and equipment, except as otherwise noted, to entirely complete the plumbing work, as specified or shown on drawings, including fixtures, drains, water supply and piping and sewers to a point five feet outside of building, all of which shall be considered as included in the plumbing work. Piping and sewers beyond a point five feet outside of building will be paid for on a unit price basis.

2. Excavation

The Contractor shall do all necessary excavation of every description in connection with the plumbing work. The bottom of all trenches shall be carefully shaped to give uniform bearing for pipes. No backfilling shall be done until test and inspection have been made by the Engineer. Trenches shall be filled by ramming and puddling, the filling being brought to the proper grade.

3. Arrangement of System

The arrangement of the system shall be as direct as possible, avoiding unnecessary bends and offsets. Vertical runs of cast iron pipe shall be firmly secured in position with strong iron pipe hooks placed under each hub, and stacks must be properly supported at the bottom. Horizontal runs under floors must be placed in position and tested before floors are laid.

Changes in direction of soil and sewer pipe shall be made by means of one-eighth bends and "Y" branches and not with one-quarter bends.

Fittings receiving risers shall be set with the top of fitting at the surface of the finished floor and shall be securely clamped in position.

All horizontal runs of sewer 6 inches or less shall have a minimum fall of ⅛ inch per foot.

4. Cast Iron Pipe and Fittings

Concealed soil, waste, drain, sewer and vent pipes in building shall be extra heavy cast iron soil pipe. Pipe shall have the maker's name cast thereon and shall be in lengths not less than 5 feet. It shall be sound and free from defects and with the inner and outer surfaces concentric and smooth and of the following weights per linear foot.

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[32] Adopted, Vol. 27, 1926, pp. 1152, 1421.

2 inches	5½ lb.	6 inches	20 lb.
3 inches	9½ lb.	7 inches	27 lb.
4 inches	13 lb.	8 inches	33½ lb.
5 inches	17 lb.	10 inches	45 lb.

Fittings for cast iron pipe shall be extra heavy cast iron of the same make as the soil pipe, and shall be of the same inside diameter as pipe with which they are connected. Unless otherwise specified, cast iron pipe and fittings must be coated with hot asphaltum both inside and outside by dipping. Fittings for the junction of cast and wrought iron pipe shall be cut at one end with full threads, and fittings, supporting risers shall have proper shoes cast on them.

Water supply pipes larger than 2½ inches diameter located below ground shall be Class "B" cast iron pipe, in accordance with the specifications of the American Water Works' Association, unless local conditions require the use of heavier pipe.

5. Wrought Iron Pipe

Wrought iron pipe shall be galvanized, genuine wrought iron of standard weights and dimensions cut with full threads with all burrs carefully reamed out before connecting. Fittings used with wrought iron soil and waste pipe shall be recessed cast iron drainage fittings. Fittings used with galvanized water supply pipe, shall be heavy beaded galvanized malleable iron except where brass is specified.

All exposed soil, waste and vent pipes in the building shall be genuine wrought iron.

6. Lead Pipe

Lead pipe shall be of the weight known as "Strong" lead pipe. All water supply pipes 2½ inches or smaller, located below ground, shall be lead pipe.

7. Brass Pipe

All exposed supply or waste pipe to fixtures, including connections to faucets, etc., shall be nickel-plated brass, unless otherwise specified.

Brass pipe for water supply shall be seamless drawn semi-annealed brass pipe of iron pipe sizes, heavily nickel plated. Brass pipe fittings shall be heavy beaded cast brass heavily nickel-plated.

8. Fixtures

The Contractor shall furnish and install complete, in proper working order, the following fixtures, locations of which are shown on the drawings. Fixtures shall be as manufactured by .... or approved equal, and shall conform to the typical types of fixtures, shown in Appendix "A" of this specification.

LIST OF FIXTURES

....

....

....

....

....

....

9. Joints and Connections

Joints for cast iron pipe shall be made with picked oakum and molten lead, and shall be air and water tight. Twelve ounces of lead shall be used for each inch of diameter of pipe for each joint. Each joint must be filled at one pouring.

Connections between iron and lead pipes shall be made with brass ferrules and neatly wiped joints. Connections between outlet of fixtures and vertical soil pipes may be made by means of sanitary tees, but all connections between horizontal runs must be made by means of "Y" branches. Openings for connections shall be closed with plugs until tested. Hand holes shall be closed immediately upon completion of each portion of the work and all sewers kept clean.

10. Suspended Sewers and Risers

All suspended sewers, wastes and downspouts, also risers in buildings, shall be genuine wrought iron pipe, and points of supports shall not be more than 5 feet apart for horizontal runs.

11. Drains

The Contractor shall install the piping for all drains of every description, including all branches, traps and accessories necessary to make the plumbing system complete.

12. Valves

In cases where there is danger of backwater from the sewer, all sewer and drain lines shall be equipped in the building with a backwater valve, properly set in a pit for accessibility. Shutoff valves throughout the plumbing system except in connection with fixtures shall be extra heavy gate valves, equipped with iron hand wheels. Valves 2 inches and under shall be brass of best quality, larger valves shall have iron bodies and brass trimmings. All valves shall be located in convenient and accessible places.

13. Sizes of Pipes

The following shall be the minimum sizes of pipe for water supply in the cases listed:

Main supply to building	(....)
To toilet rooms	¾ in.
To individual sill cock	¾ in.
To individual sink	¾ in.
To individual urinal	½ in.
To individual lavatory	½ in.
To individual closet	½ in.
To heating boiler	¾ in.

Air chambers shall be provided in the water supply pipe at its connection to each fixture, to prevent water hammer. This chamber shall be equal, in capacity, to one foot of the supply pipe.

The minimum size of waste pipes for fixtures shall be as follows:

From individual closets	4 in.
From individual lavoratories	1½ in.
From individual urinals	2 in.
From individual slop sinks	3 in.

The minimum sized vent pipes shall be as follows:

For closet traps	2 in.
For lavatory	1½ in.
For urinals	2 in.
For slop sinks	2 in.

14. Openings in Floors or Walls

Wherever exposed plumbing pipes pass through floors or walls they shall be provided with galvanized iron pipe sleeves with nickel plated brass floor or ceiling plates. Wherever pipes pass through concrete or masonry, the Contractor shall provide iron pipe sleeves of the requisite size, locating these for the masonry contractor, and assume all responsibility for their correct location.

15. Soil and Vent Stacks

Main stacks shall be extended through roof of building and to a height not less than 12 inches above the top thereof. Stacks extending through the roof must increase their diameter 2 inches at a point 6 inches below the roof. No stack extending through the roof shall be less than 4 inches in diameter.

Fixtures shall be revented except in cases where but a single fixture is attached to a stack, in which case this fixture need not be revented. Vent fittings shall be combination fittings of a type that will comply with local ordinances. Branch vents shall be cast iron and must be connected into the main vent stack below the roof. That portion of the stack above the roof shall be properly flashed with 4-lb. sheet lead with 15-inch square collar. Flashing shall be turned down into the top of stack, and shall be made watertight.

16. Meter, Pressure Regulator, Etc.

The Contractor shall install in a suitable concrete pit a water meter of an approved type, and make the necessary connection to the water main. Where the pressure in the main exceeds 40 lb. he shall install in connection with the meter a water pressure regulator of an approved type, properly adjusted to protect the fixtures in the building. He shall provide and set on the main supply line a stop and waste cock which will drain the entire piping system in the building. He shall provide in the pit with the meter a valve which will cut off the entire water supply from the building.

17. Traps and Cleanouts

Approved traps with cleanouts, equipped with brass plugs, shall be placed under each fixture. Brass plugs for cleanouts shall be placed at the foot of each soil and waste riser above the floor and at all changes in direction of soil and waste pipes. Cleanouts connected below floors must be brought up level with floors by means of "Y" fittings and one-eighth bends. All plugs must be full size of pipes.

18. Pipe Covering

Hot water piping shall be covered with ¾-inch wool felt covering of an approved brand, lined with asbestos on the inside and covered with eight-ounce canvas jacket, banded with three lacquered bands to each section.

Cold water pipe, in concealed positions, behind plastered walls or ceilings or carried in tunnels with steam or hot water heating pipes, shall be covered as described above, except that the lining shall be of tarred felt instead of asbestos. Fittings shall be covered with hair felt, with canvas jackets. All covering shall be applied in a manner to prevent sweating.

19. Slate Compartment Work

The Contractor shall furnish and set all slate compartment work called for on drawings, complete, in accordance with details. Slate shall be black ribbed slate, of best quality. Trimmings, including coat hooks and toilet paperholders, shall be nickel-plated brass.

Doors for slate water closet stalls will be furnished and installed by carpenters, but hardware for same shall be furnished by the plumbing contractor. Doors for wooden closet stalls will be furnished and installed by carpenter, complete with hardware.

20. Tests

The system shall be subject to the following test, to be made entirely at the expense of the Contractor:

After all pipes are "roughed in" and before the final connections are made with fixtures and sewer, all openings shall be closed and pipes filled with water to roof line. The water shall be maintained at this level until the job has been inspected and approved.

Should any defect appear, it shall be remedied and any defective material shall be replaced with sound material. After the water has been turned on and the traps filled, a peppermint test shall be made by placing two ounces of oil of peppermint in each stack. The system, with all traps full, must retain the peppermint odor from all parts of the building.

These tests shall be repeated until the work is approved by the Engineer.

21. Gas Piping

The Contractor shall install piping for gas with outlets located where shown on drawings. The supply line shall be of a size recommended by Gas Company supplying the service and all piping shall meet the approval of the Gas Company. Pipes shall be coated with asphaltum after installation. A meter shall be installed as required by the rules of the Gas Company, with necessary valves and shutoff. Gas piping shall be tested as required by the Gas Company and certificate of inspection delivered to the Railway Company. The gas meter shall be placed in a convenient and accessible location.

22. Fire Protection

The Contractor shall install, complete, all supply lines required for fire protection, including all connections to water main, and all fire hydrants and connections as indicated on the drawings or specified.

All pipe for outside fire protection lines shall conform to and be laid in accordance with the American Water Works' Association specifications for cast iron water pipe and special castings.

Where the size of fire lines is 6 inches or larger, 6-inch two-way standard hydrants equipped with drain and auxiliary valves shall be used.

Where fire fighting apparatus is to be provided inside the building, independent standpipes, 2½ inches or larger, shall be installed so as not to be more than 200 feet apart on each floor. Each standpipe shall be equipped with a standard 2½-inch threaded hose connection located five feet above the floor level. Each standpipe shall be provided with a 2½ by 1½-inch reducing coupler, an approved hose reel, or rack, together with hose, nozzle and couplings, as specified. Not more than 100 feet of hose shall be provided for each connection, but the lengths must be such that every part of each floor may be reached.

Where buildings are heated Underwriters' 1½-inch linen hose must be used. Where buildings are not heated Underwriters' 1½-inch cotton rubber-lined hose must be used. Hose for outside use shall be Underwriters' approved 2½-inch double jacket fire hose.

Nozzles for outside hose shall be Underwriters' play pipe with 1⅛-inch orifice. Each hose inside of buildings shall be equipped with a brass nozzle 12 inches long, with a ½-inch orifice.

All fire-fighting apparatus shall be in conformity with the requirements of the National Board of Fire Underwriters. It shall also conform to the requirements of the local fire department so far as hose connections are concerned.

23. Local Rules and Ordinances

The Contractor shall comply in all cases with the local sanitary, gas and fire protection ordinances, and shall obtain and pay for all permits and inspection fees.

24. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specifications.

The following types of plumbing fixtures are for guidance in use of these plumbing specifications, and comprise the Appendix A, referred to in Article 8, Fixtures.

TYPICAL PLUMBING FIXTURES

FOR

RAILWAY BUILDINGS

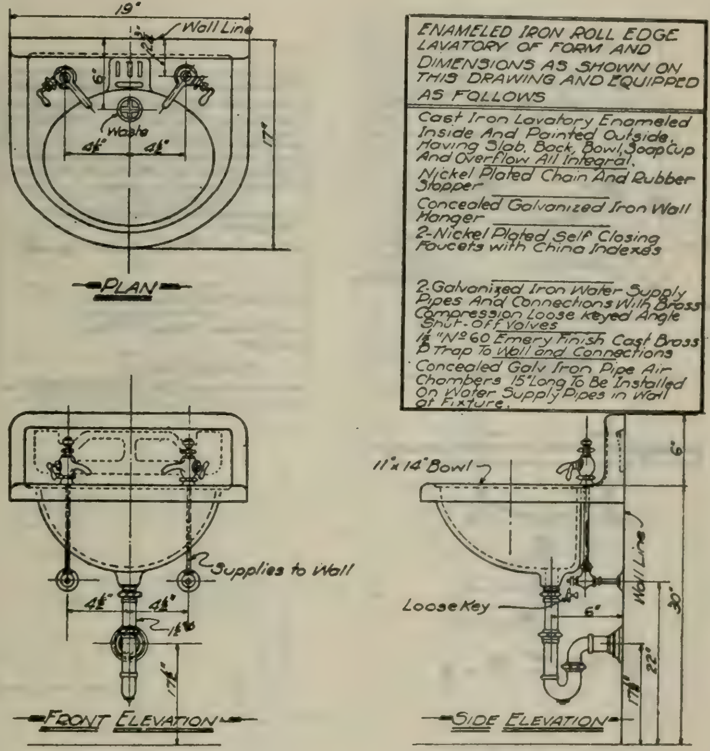
APPENDIX A

SUPPLEMENTING PLUMBING SPECIFICATIONS

TYPICAL PLUMBING FIXTURES

INDEX

Lavatory No. 1 - Enameled Cast Iron Wall Type
Lavatory No. 2 - Enameled Cast Iron Corner Type
Lavatory No. 3 - Vitreous Wall Type
Lavatory No. 4 - Vitreous Corner Wall Type
Lavatory No. 5 - Double Battery Type
Closet No. 1 - Syphon Jet Seat Operating Flush Valve Type
Closet No. 2 - Syphon Jet Seat Operating Type
Closet No. 3 - Wash Down Jet Seat Operating Type
Closets No. 4&5 - Frost Proof Types
Closet Stall No. 1 - Slate Type Without Doors
Closet Stall No. 2 - Slate Type With Doors
Closet Stall No. 3 - Wood Type With Doors
Urinal No. 1 - Floor Type
Urinal No. 2 - Automatic Trough Type
Urinal No. 3 - Automatic One Piece Trough Type
Urinal No. 4 - Syphon Jet Vitreous Type
Drinking Fountain No. 1 - Pedestal Type
Drinking Fountain No. 2 - Wall Type
Slop Sink With Back.



ENAMELED IRON ROLL EDGE LAVATORY OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS

Cast Iron Lavatory Enameled Inside And Painted Outside, Having Slab, Back, Bowl, Soap Cup And Overflow All Integral.

Nickel Plated Chain And Rubber Stopper

Concealed Galvanized Iron Wall Hanger

2-Nickel Plated Self Closing Faucets with China Indexes

2 Galvanized Iron Water Supply Pipes And Connections With Brass Compression Loose Keyed Angle Shut-Off Valves

1¼" Nº 60 Emery Finish Cast Brass P Trap To Wall and Connections

Concealed Galv Iron Pipe Air Chambers 15" Long To Be Installed On Water Supply Pipes in Wall at Fixture.

A.R.E.A.

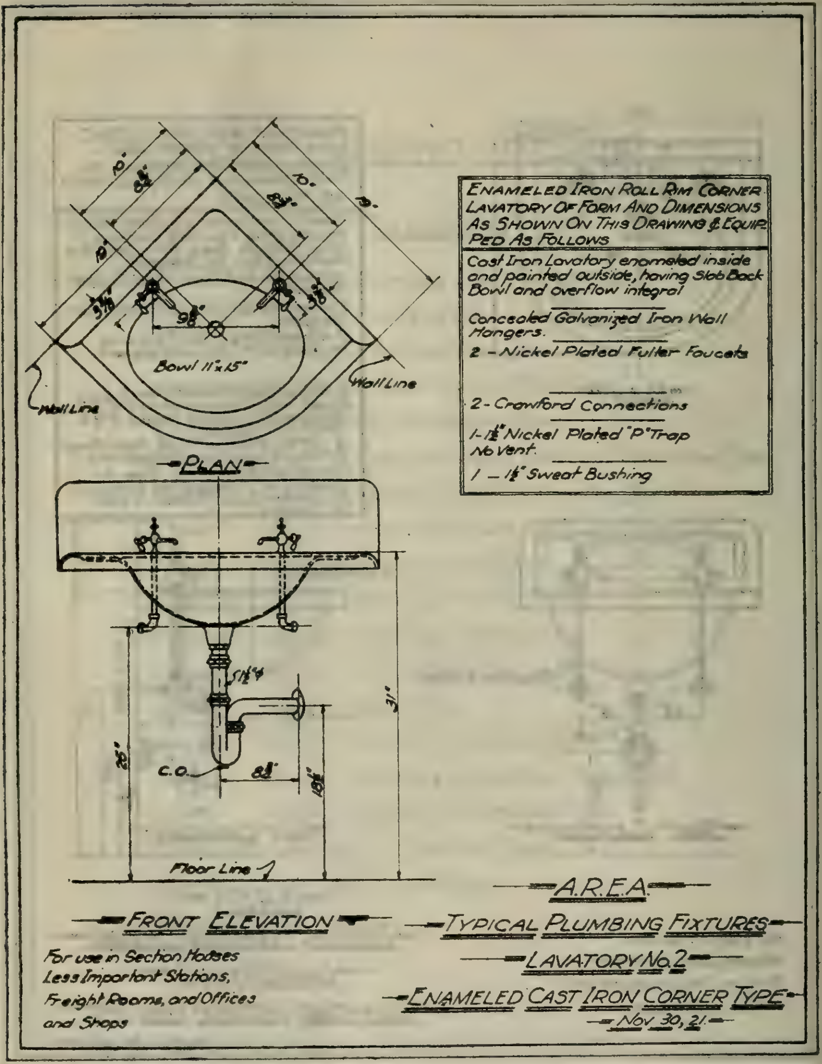
TYPICAL PLUMBING FIXTURES

LAVATORY No. 1

ENAMELED CAST IRON WALL TYPE

Nov. 30, 1921

For use in Section Houses, Less Important Stations, Freight Rooms and Offices, and Shops.



ENAMELED IRON ROLL RIM CORNER LAVATORY OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS

Cast Iron Lavatory enameled inside and painted outside, having Slab Back Bowl and overflow integral

Concealed Galvanized Iron Wall Hangers.

2 – Nickel Plated Fuller Faucets

2 - Crawford Connections

1-1½" Nickel Plated "P" Trap No Vent.

1 – 1½" Sweat Bushing

For use in Section Houses
Less Important Stations,
Freight Rooms, and Offices
and Shops

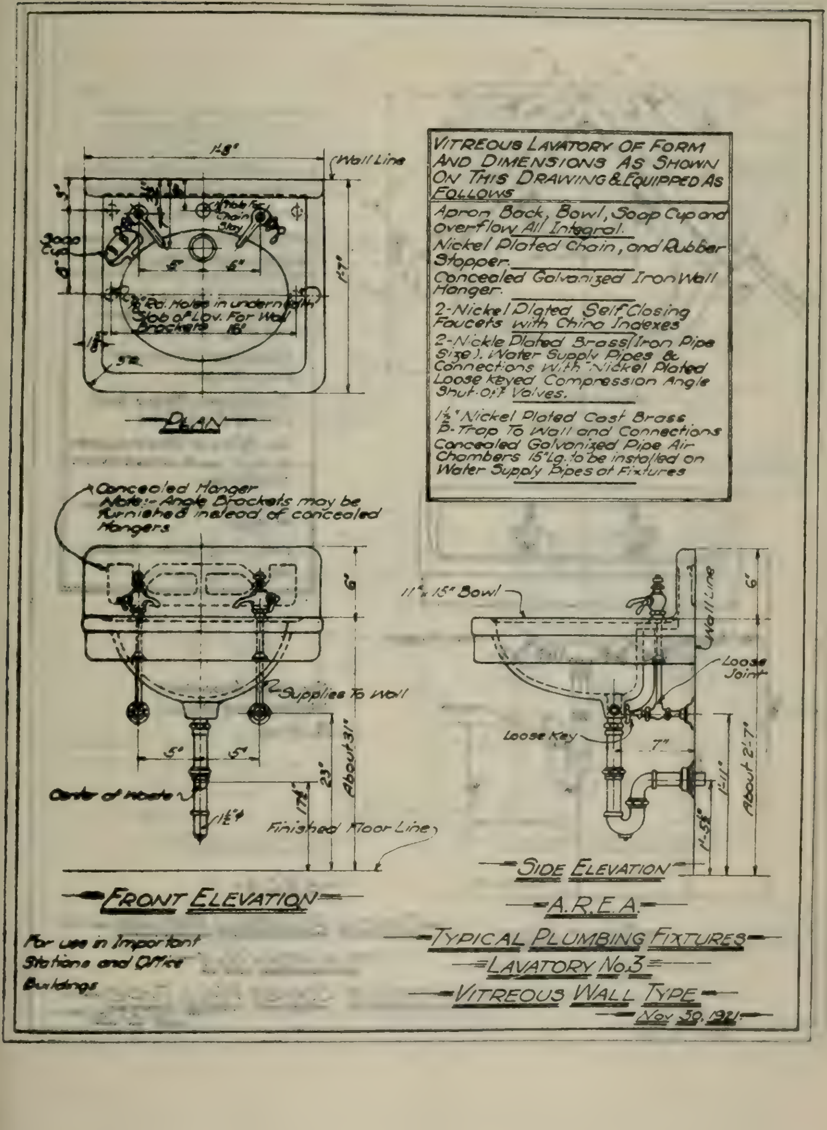
A.R.E.A.

TYPICAL PLUMBING FIXTURES

LAVATORY No. 2

ENAMELED CAST IRON CORNER TYPE

Nov. 30, 21.



Note:- Angle Brackets may be furnished instead of concealed Hangers

VITREOUS LAVATORY OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS

Apron Back, Bowl, Soap Cup and overflow All Integral.

Nickel Plated Chain, and Rubber Stopper.

Concealed Galvanized Iron Wall Hanger.

2-Nickel Plated Self Closing Faucets with China Indexes

2-Nickle Plated Brass (Iron Pipe Size). Water Supply Pipes & Connections With Nickel Plated Loose keyed Compression Angle Shut-off Valves.

1½" Nickel Plated Cast Brass P-Trap To Wall and Connections Concealed Galvanized Pipe Air Chambers 15" Lg. to be installed on Water Supply Pipes at Fixtures

For use in Important Stations and Office Buildings

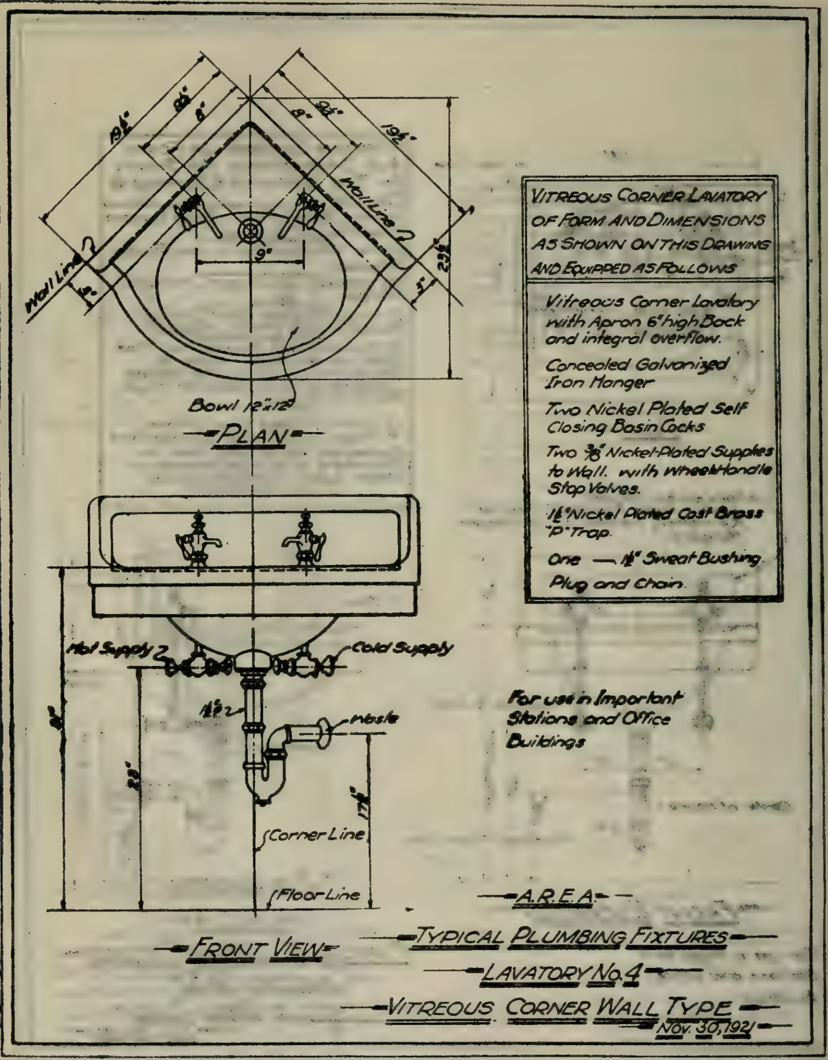
A.R.E.A.

TYPICAL PLUMBING FIXTURES

LAVATORY No. 3

VITREOUS WALL TYPE

Nov. 30, 1921.



VITREOUS CORNER LAVATORY OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS

Vitreous Corner Lavatory with Apron 6" high Back and integral overflow.

Concealed Galvanized Iron Hanger

Two Nickel Plated Self Closing Basin Cocks

Two ⅜" Nickel-Plated Supplies to Wall. with Wheel Handle Stop Valves.

1½" Nickel Plated Cast Brass "P" Trap.

One — 1½" Sweat Bushing.

Plug and Chain.

For use in Important Stations and Office Buildings

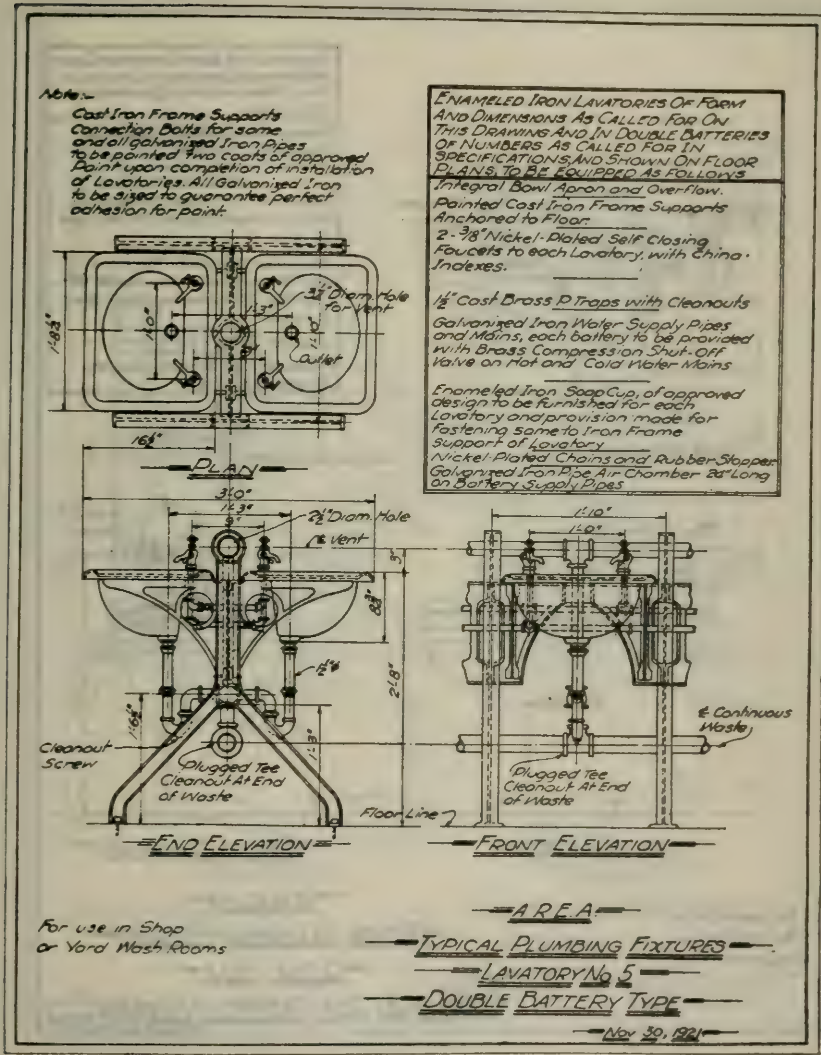
A.R.E.A.

TYPICAL PLUMBING FIXTURES

LAVATORY No. 4

VITREOUS CORNER WALL TYPE

Nov. 30, 1921



Note:-

Cast Iron Frame Supports Connection Bolts for same and all galvanized Iron Pipes to be painted two coats of approved Paint upon completion of installation of Lavatories. All Galvanized Iron to be sized to guarantee perfect adhesion for paint.

ENAMELED IRON LAVATORIES OF FORM AND DIMENSIONS AS CALLED FOR ON THIS DRAWING AND IN DOUBLE BATTERIES OF NUMBERS AS CALLED FOR IN SPECIFICATIONS, AND SHOWN ON FLOOR PLANS, TO BE EQUIPPED AS FOLLOWS

Integral Bowl Apron and Overflow.

Painted Cast Iron Frame Supports Anchored to Floor.

2-3/8" Nickel-Plated Self Closing Faucets to each Lavatory, with China Indexes.

1½" Cast Brass P Traps with Cleanouts

Galvanized Iron Water Supply Pipes and Mains, each battery to be provided with Brass Compression Shut-Off Valve on Hot and Cold Water Mains

Enameled Iron Soap Cup, of approved design to be furnished for each Lavatory and provision made for fastening same to Iron Frame Support of Lavatory

Nickel-Plated Chains and Rubber Stopper.

Galvanized Iron Pipe Air Chamber 24" Long on Battery Supply Pipes

For use in Shop or Yard Wash Rooms

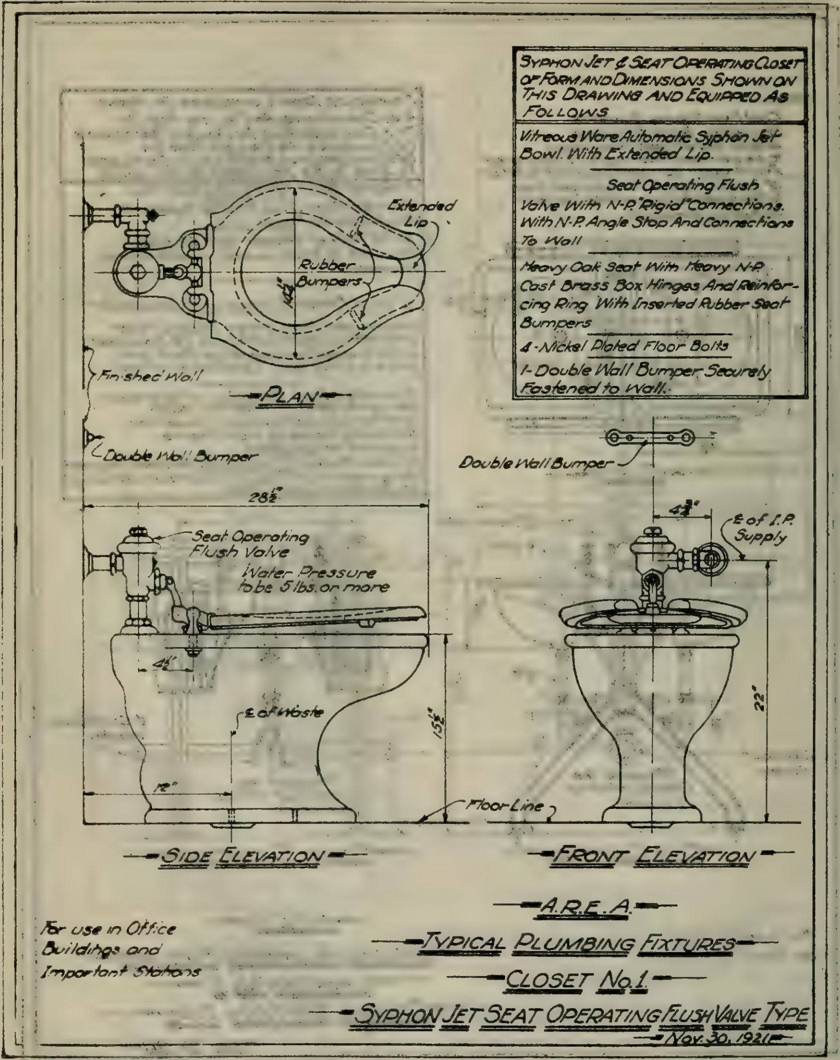
AREA A

TYPICAL PLUMBING FIXTURES

LAVATORY No 5

DOUBLE BATTERY TYPE

Nov 30, 1921



SYPHON JET & SEAT OPERATING CLOSET OF FORM AND DIMENSIONS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS

Vitreous Ware Automatic Syphon Jet Bowl With Extended Lip.

Seat Operating Flush Valve With N-P "Rigid" Connections. With N-P Angle Stop And Connections To Wall

Heavy Oak Seat With Heavy N-P Cast Brass Box Hinges And Reinforcing Ring With Inserted Rubber Seat Bumpers

4-Nickel Plated Floor Bolts

1-Double Wall Bumper Securely Fastened to Wall.

For use in Office Buildings and Important Stations

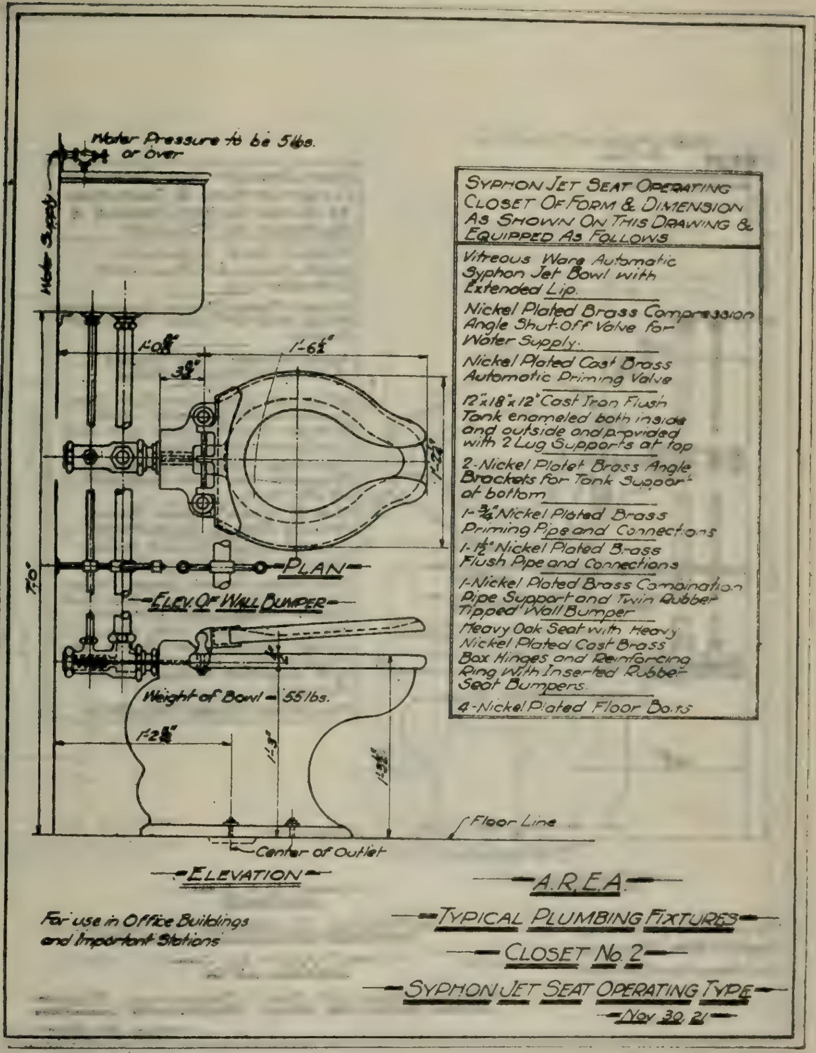
A.R.E.A.

TYPICAL PLUMBING FIXTURES

CLOSET No. 1

SYPHON JET SEAT OPERATING FLUSH VALVE TYPE

Nov. 30, 1921



SYPHON JET SEAT OPERATING CLOSET OF FORM & DIMENSION AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS

Vitreous Ware Automatic Syphon Jet Bowl with Extended Lip.

Nickel Plated Brass Compression Angle Shut-Off Valve for Water Supply.

Nickel Plated Cast Brass Automatic Priming Valve

12"x18"x12" Cast Iron Flush Tank enameled both inside and outside and provided with 2 Lug Supports at top

2-Nickel Plated Brass Angle Brackets for Tank Support at bottom

1-¾" Nickel Plated Brass Priming Pipe and Connections

1-1½" Nickel Plated Brass Flush Pipe and Connections

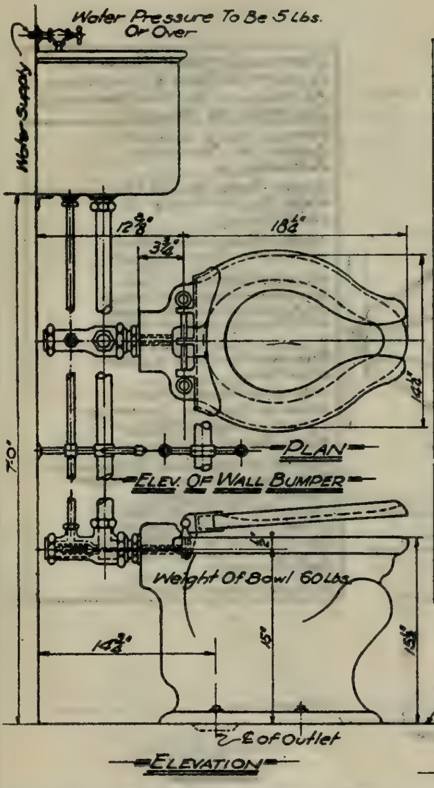
1-Nickel Plated Brass Combination Pipe Support and Twin Rubber Tipped Wall Bumper

Heavy Oak Seat with Heavy Nickel Plated Cast Brass Box Hinges and Reinforcing Ring With Inserted Rubber Seat Bumpers.

4-Nickel Plated Floor Bolts

For use in Office Buildings
and Important Stations

A.R.E.A.
TYPICAL PLUMBING FIXTURES
CLOSET No. 2
SYPHON JET SEAT OPERATING TYPE
Nov. 30, 21



WASH-DOWN-JET SEAT OPERATING CLOSET OF FORM & DIMENSION AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS.

Vitreous Ware Automatic Wash-Down-Jet Bowl With Extended Lip.

Nickel Plated Brass Compression Angle Shut Off Valve For Water Supply.

Nickel Plated Cast Brass Automatic Priming Valve.

12"x18"x12" Cast Iron Flush Tank Enameled Both Inside And Outside And Provided With Two Lug Supports At Top.

Two Nickel Plated Brass Angle Brackets For Tank Support At Bottom.

One 3/4" Nickel Plated Brass Priming Pipe & Connections.

One 1½" Nickel Plated Brass Flush Pipe & Connections.

One Nickel Plated Brass Combination Pipe Support And Twin Rubber Tipped Wall Bumper

Heavy Oak Seat With Heavy Nickel Plated Cast Brass Box Hinges And Reinforcing Ring With Inserted Rubber Seat Bumpers

Four Nickel Plated Floor Bolts

For use in Freight Rooms,
Freight Offices, Shops and
Less Important Stations

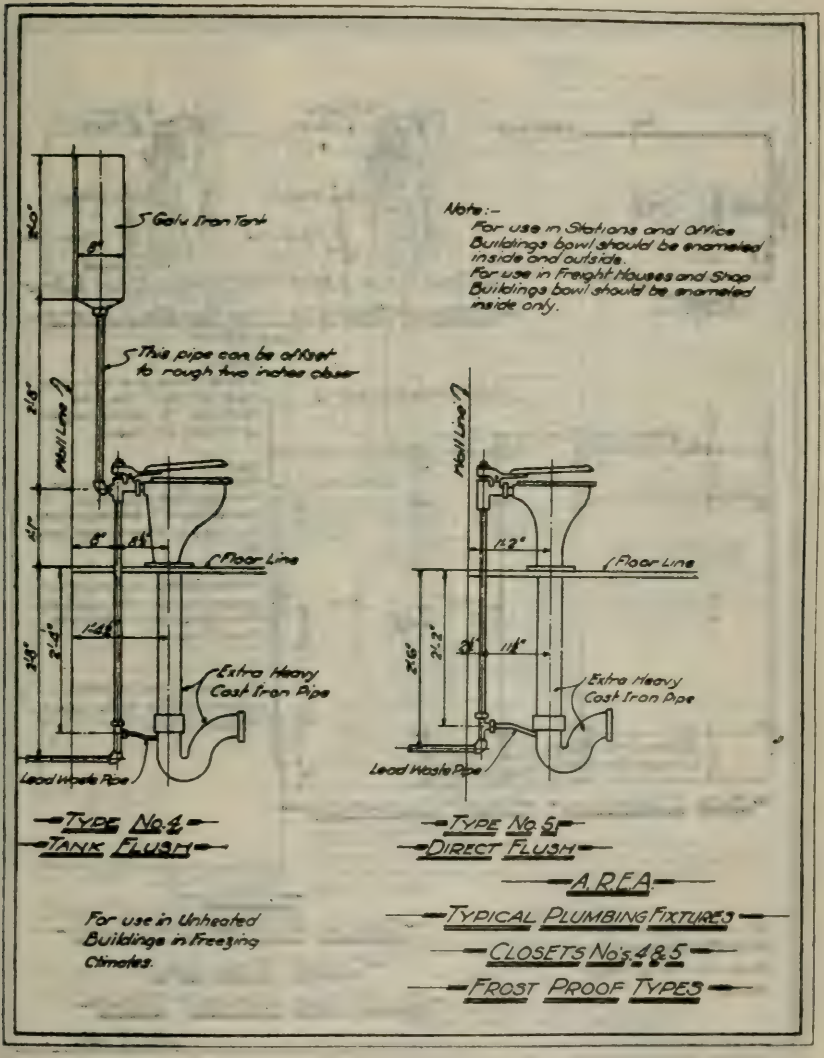
A.R.E.A.

TYPICAL PLUMBING FIXTURES

CLOSET No. 3.

WASH-DOWN-JET SEAT OPERATING TYPE

Nov. 30, 1921



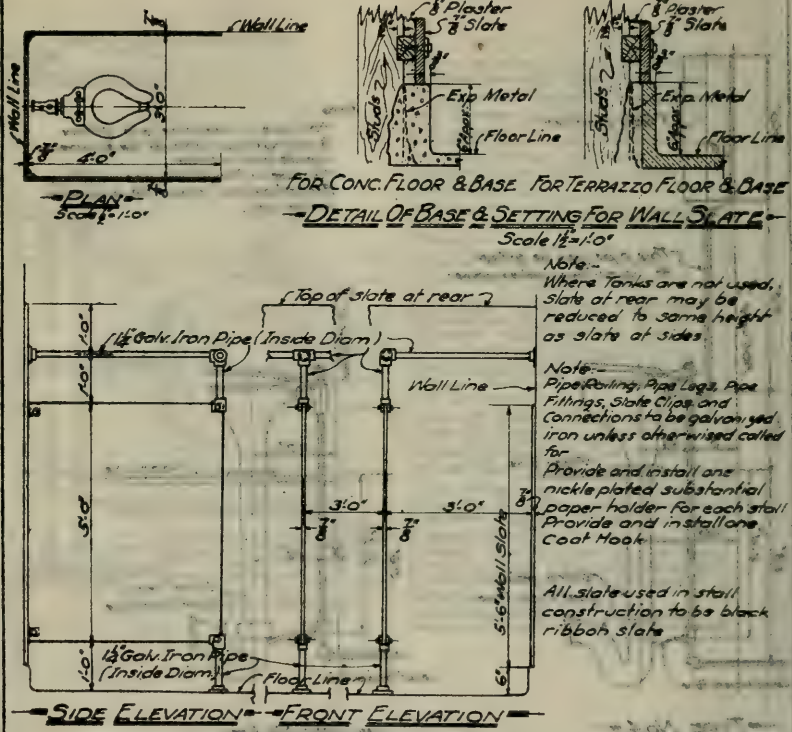
Note:-
For use in Stations and Office Buildings bowl should be enameled inside and outside.
For use in Freight Houses and Shop Buildings bowl should be enameled inside only.

TYPE No. 4
TANK FLUSH

For use in Unheated Buildings in Freezing Climates.

TYPE No. 5
DIRECT FLUSH

A.R.E.A.
TYPICAL PLUMBING FIXTURES
CLOSETS No's 4 & 5
FROST PROOF TYPES



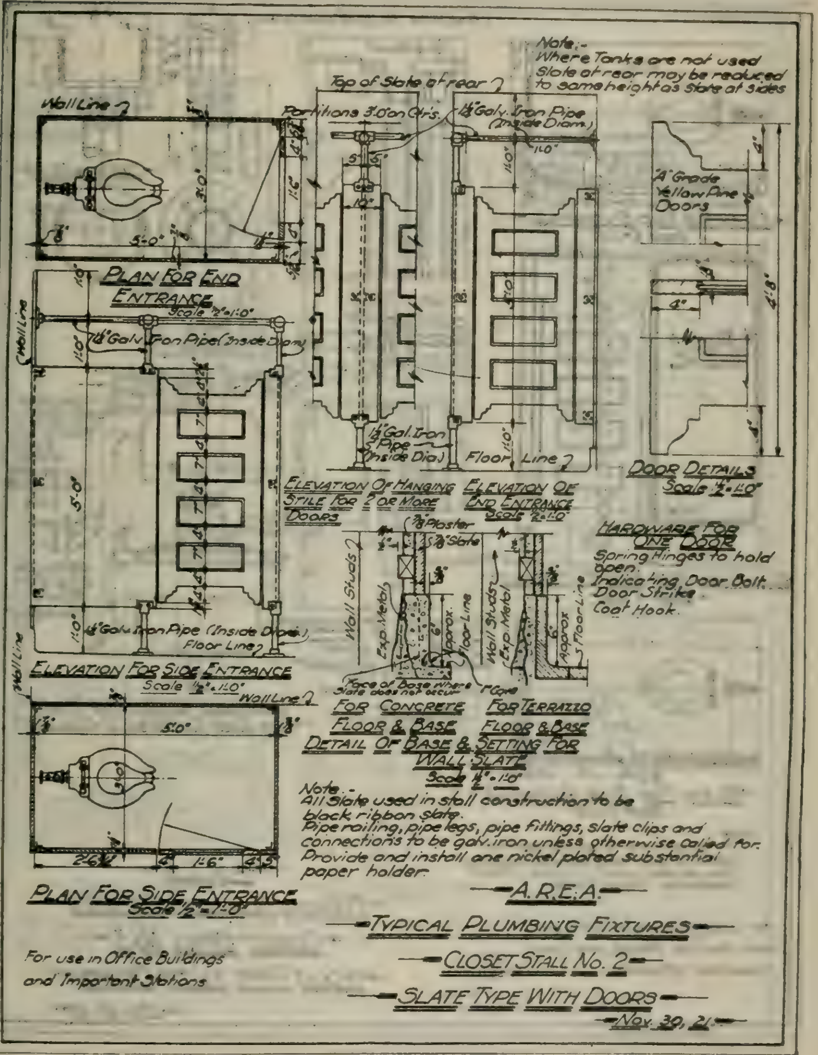
Note:-
Where Tanks are not used, slate at rear may be reduced to same height as slate at sides

Note:-
Pipe Railing, Pipe Legs, Pipe Fittings, Slate Clips and Connections to be galvanized iron unless otherwised called for
Provide and install one nickle plated substantial paper holder for each stall
Provide and install one Coat Hook

All slate used in stall construction to be black ribbon slate

For use in Shop and Yard Toilet Buildings and Ware Room Portion of Freight Houses

—A.R.E.A.—
—TYPICAL PLUMBING FIXTURES—
—CLOSET STALL No. 1—
—SLATE TYPE WITHOUT DOORS—
—Nov. 30, 1921—


Wall Line
Top of Slate at rear
Partitions 3'0" on Ctr's.
1¼" Galv. Iron Pipe (Inside Diam.)
1'-0"
5'-0"
3'-0"
1'-6"
PLAN FOR END ENTRANCE
Scale ½"=1'-0"
1¼" Galv. Iron Pipe (Inside Diam.)
Wall Line
1'-0"
5'-0"
1¼" Galv. Iron Pipe (Inside Diam.)
Floor Line
ELEVATION FOR SIDE ENTRANCE
Scale ½"=1'-0"
1¼" Gal. Iron Pipe (Inside Dia.)
Floor Line
ELEVATION OF HANGING STILE FOR 2 OR MORE DOORS
ELEVATION OF END ENTRANCE
Scale ½"=1'-0"
"A" Grade Yellow Pine Doors
4'-8"
4"
DOOR DETAILS
Scale ½"=1'-0"
⅞" Plaster
⅞" Slate
Wall Studs
Exp. Metal
Approx.
Floor Line
Face of Base where Slate does not occur
1" Core
FOR CONCRETE FLOOR & BASE
FOR TERRAZZO FLOOR & BASE
DETAIL OF BASE & SETTING FOR WALL SLATE
Scale ½"=1'-0"
Wall Line
5'-0"
2'-6½"
1'-6"
PLAN FOR SIDE ENTRANCE
Scale ½"=1'-0"

Note:-
Where Tanks are not used
Slate at rear may be reduced
to same height as Slate at sides

HARDWARE FOR ONE DOOR

Spring Hinges to hold open.
Indicating Door Bolt.
Door Strike
Coat Hook.

Note.-
All Slate used in stall construction to be black ribbon slate.
Pipe railing, pipe legs, pipe fittings, slate clips and connections to be galv. iron unless otherwise called for.
Provide and install one nickel plated substantial paper holder.

For use in Office Buildings
and Important Stations

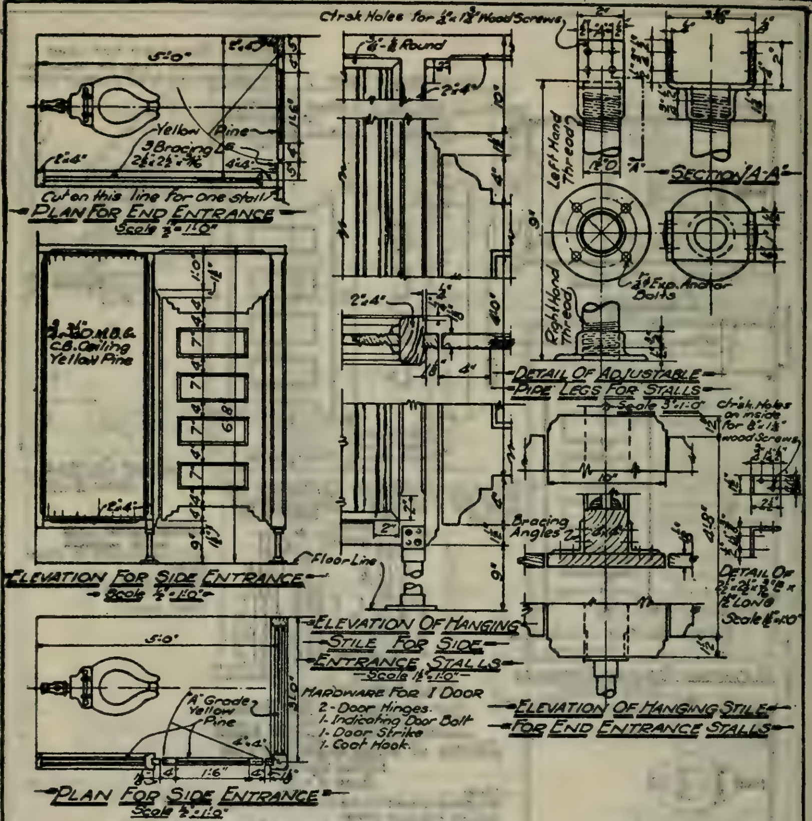
A.R.E.A.

TYPICAL PLUMBING FIXTURES

CLOSET STALL No. 2

SLATE TYPE WITH DOORS

Nov. 30, 21.

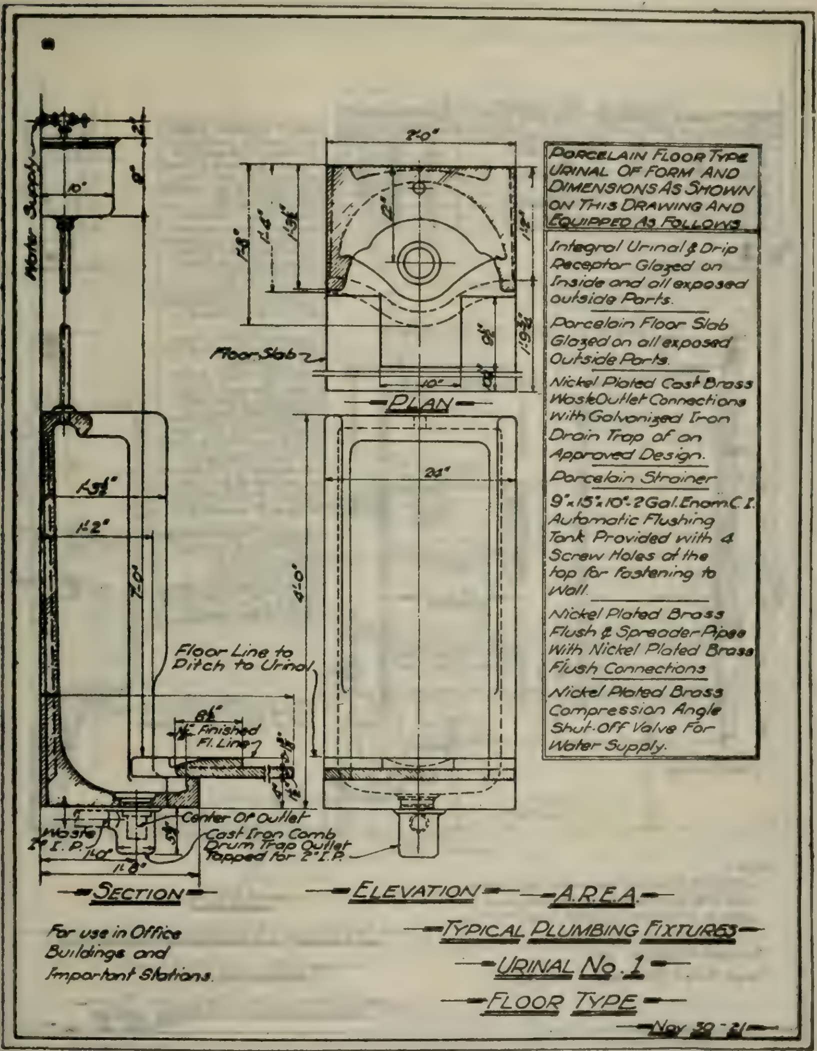

Ctrsk Holes for ¼"x 1⅜" Wood Screws
5'-0"
2"x 4"
Yellow Pine
3 Bracing Ls 2½"x 2½"x 5/16"
4"x 4"
11½"
Cut on this line for one stall
PLAN FOR END ENTRANCE
Scale ½"=1'-0"
2"x 4" M.B.& C.B. Ceiling Yellow Pine
1'-0"
6'-8"
9"
Floor Line
ELEVATION FOR SIDE ENTRANCE
Scale ½"=1'-0"
¾"-⅛ Round
2"x 4"
10"
4"
9"
2"
ELEVATION OF HANGING STILE FOR SIDE ENTRANCE STALLS
Scale 1½"=1'-0"
Left Hand Thread
Right Hand Thread
1¼"O
"A"
SECTION "A-A"
¼" Exp. Anchor Bolts
DETAIL OF ADJUSTABLE PIPE LEGS FOR STALLS
Scale 3"=1'-0"
Ctrsk. Holes on inside for ⅛"x 1⅛" wood Screws
10"
2½"
Bracing Angles
4'-8"
DETAIL OF 2½"x 2½"x 5/16" L x 1½" LONG
Scale 1½"=1'-0"
ELEVATION OF HANGING STILE FOR END ENTRANCE STALLS
5'-0"
"A" Grade Yellow Pine
4"x 4"
1'-6"
4"
PLAN FOR SIDE ENTRANCE
Scale ½"=1'-0"

HARDWARE FOR 1 DOOR
- 2 - Door Hinges.
- 1 - Indicating Door Bolt
- 1 - Door Strike
- 1 - Coat Hook.

Note:-
All woodwork to be painted two coats of approved paint as directed
Provide and install 1-Nickel Plated Substantial Paper Holder

For Use in Freight Offices and Rooms, Shops, and Less Important Stations.

A.R.E.A.
TYPICAL PLUMBING FIXTURES
CLOSET STALL No. 3
WOOD TYPE WITH DOORS
Nov. 30.-21



PORCELAIN FLOOR TYPE URINAL OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS

Integral Urinal & Drip Receptor Glazed on Inside and all exposed outside Parts.

Porcelain Floor Slab Glazed on all exposed Outside Parts.

Nickel Plated Cast Brass Waste Outlet Connections With Galvanized Iron Drain Trap of an Approved Design.

Porcelain Strainer

9"x15"x10"-2 Gal. Enam. C. I. Automatic Flushing Tank Provided with 4 Screw Holes at the top for Fastening to Wall.

Nickel Plated Brass Flush & Spreader Pipes With Nickel Plated Brass Flush Connections

Nickel Plated Brass Compression Angle Shut-Off Valve For Water Supply.

For use in Office Buildings and Important Stations.

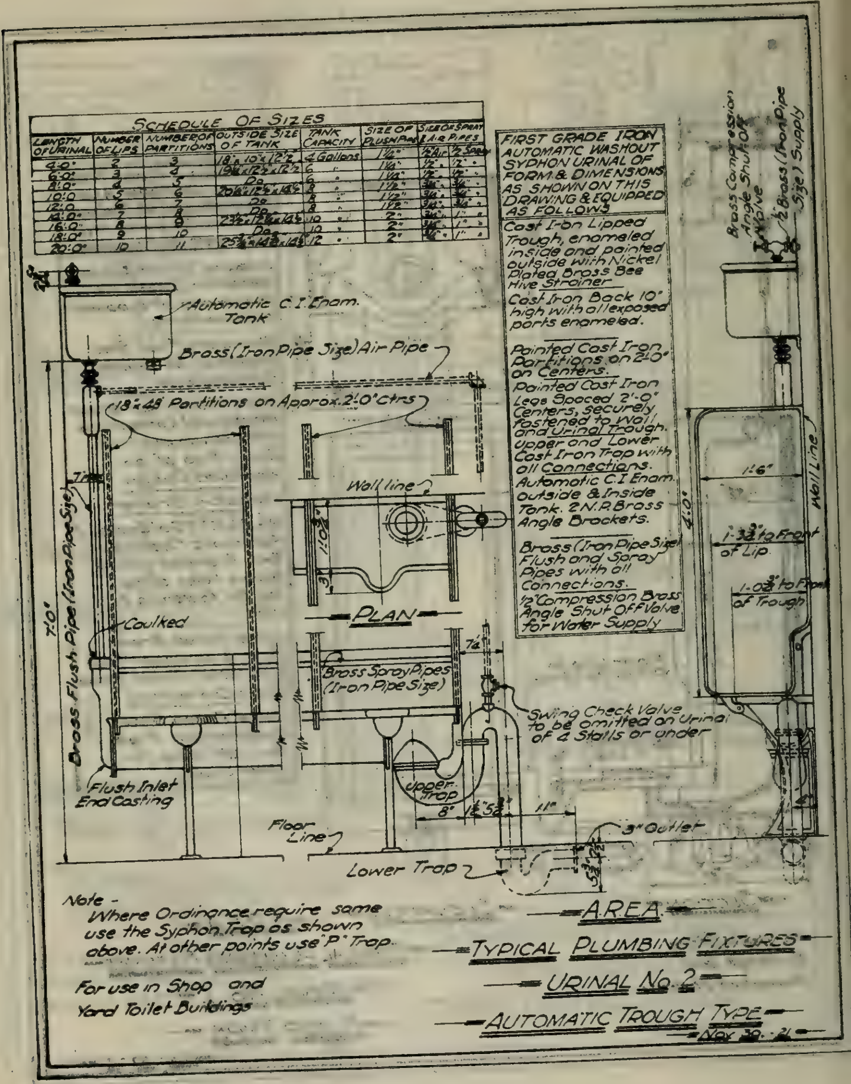
A.R.E.A.

TYPICAL PLUMBING FIXTURES

URINAL No. 1

FLOOR TYPE

Nov 30-21



SCHEDULE OF SIZES

LENGTH OF URINAL	NUMBER OF LIPS	NUMBER OF PARTITIONS	OUTSIDE SIZE OF TANK	TANK CAPACITY	SIZE OF FLUSH PIPE	SIZE OF SPRAY & AIR PIPES	
						Air	Spray
4'-0"	2	3	18" x 10" x 12½"	4 Gallons	1¼"	½"	½"
6'-0"	3	4	19¾" x 12½" x 12½"	6 "	1¼"	½" "	½" "
8'-0"	4	5	Do	6 "	1¼"	½" "	½" "
10'-0	5	6	20⅞" x 12¾" x 14⅝"	8 "	1½"	¾" "	¾" "
12'-0	6	7	Do	8 "	1½"	¾" "	¾" "
14'-0"	7	8	Do	8 "	1½"	¾" "	¾" "
16'-0"	8	9	23½" x 12¾" x 14⅝"	10 "	2"	¾" "	1" "
18'-0"	9	10	Do	10 "	2"	¾" "	1" "
20'-0"	10	11	25⅝" x 14⅝" x 14⅝"	12 "	2"	¾" "	1" "

FIRST GRADE IRON AUTOMATIC WASHOUT SYPHON URINAL OF FORM & DIMENSIONS AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS

Cast Iron Lipped Trough, enameled inside and painted outside with Nickel Plated Brass Bee Hive Strainer

Cast Iron Back 10" high with all exposed parts enameled.

Painted Cast Iron Partitions on 2'-0" on Centers.

Painted Cast Iron Legs Spaced 2'-0" Centers, securely fastened to Wall and Urinal Trough.

Upper and Lower Cast Iron Trap with all Connections.

Automatic C.I. Enam. outside & Inside Tank. 2 N.P. Brass Angle Brackets.

Brass (Iron Pipe Size) Flush and Spray Pipes with all Connections.

½" Compression Brass Angle Shut Off Valve for Water Supply

Automatic C.I. Enam. Tank
Brass (Iron Pipe Size) Air Pipe
18" x 48" Partitions on Approx. 2'-0" ctrs
Brass Flush Pipe (Iron Pipe Size)
7'-0"
Caulked
Flush Inlet End Casting
Wall line
1'-0¾"
PLAN
7¼"
Brass Spray Pipes (Iron Pipe Size)
Swing Check Valve to be omitted on Urinal of 4 Stalls or under
Upper Trap
8"
5¾"
11"
Floor Line
Lower Trap
3" Outlet
Brass Compression Angle Shut-Off Valve
½" Brass (Iron Pipe Size) Supply
1'-6"
Wall Line
4'-0"
1'-3¾" to Front of Lip
1'-0¾" to Front of Trough

Note - Where Ordinance require same use the Syphon Trap as shown above. At other points use "P" Trap.

For use in Shop and Yard Toilet Buildings

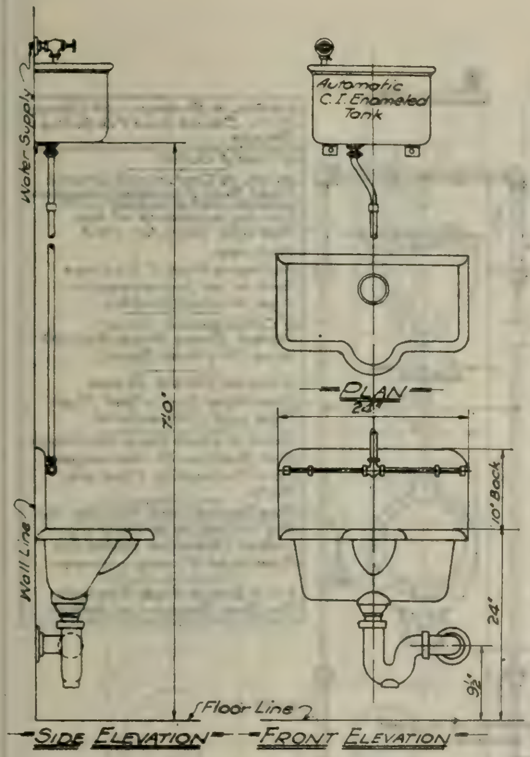
AREA

TYPICAL PLUMBING FIXTURES

URINAL No. 2

AUTOMATIC TROUGH TYPE

Nov. 30 - 21



FIRST GRADE CAST IRON AUTOMATIC FLUSHING ROLL-RIM URINAL OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS.

Cast Iron Lipped Trough Enameled Inside And Painted Outside With Integral Back Having All Exposed Parts Enameled.

Nickel Plated Brass Bee Hive Strainer

Concealed Galvanized Iron Wall Supports For Urinal.

2" Painted Cast Iron "P" Trap To Wall With Cleanout

18"x10"x12½" Automatic C.I. Enameled outside and inside Tank, 2" N P Brass Angle Brackets

½" Compression Nickel Plated Brass Angle Shut Off Valve for Water Supply.

1¼" Nickel Plated Brass (Iron Pipe Size) Flush Pipe And Connections

1¼" Nickel Plated Brass (Iron Pipe Size) Spreader With Nickel Plated Brass Caps And Connections

For use in Freight Offices, Freight Rooms, Shops, and less important Stations

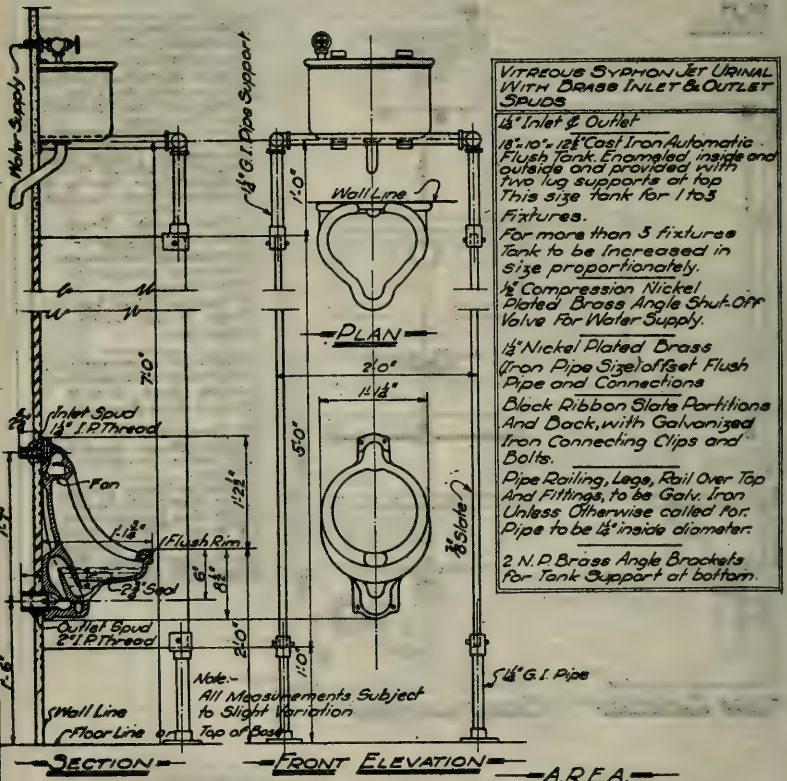
AREA

TYPICAL PLUMBING FIXTURES

URINAL No. 3

AUTOMATIC ONE PIECE TROUGH TYPE

Nov. 30, 1921



Note.-
All Measurements Subject to Slight Variation

VITREOUS SYPHON JET URINAL WITH BRASS INLET & OUTLET SPUDS

$1\frac{1}{4}$" Inlet & Outlet

$18" \times 10" \times 12\frac{1}{2}"$ Cast Iron Automatic Flush Tank. Enameled inside and outside and provided with two lug supports at top This size tank for 1 to 3 Fixtures.

For more than 3 fixtures Tank to be Increased in size proportionately.

$\frac{1}{2}$" Compression Nickel Plated Brass Angle Shut-Off Valve For Water Supply.

$1\frac{1}{4}$" Nickel Plated Brass (Iron Pipe Size) offset Flush Pipe and Connections

Black Ribbon Slate Partitions And Back, with Galvanized Iron Connecting Clips and Bolts.

Pipe Railing, Legs, Rail Over Top And Fittings, to be Galv. Iron Unless Otherwise called for. Pipe to be $1\frac{1}{4}$" inside diameter.

2 N.P. Brass Angle Brackets for Tank Support at bottom.

A.R.E.A.

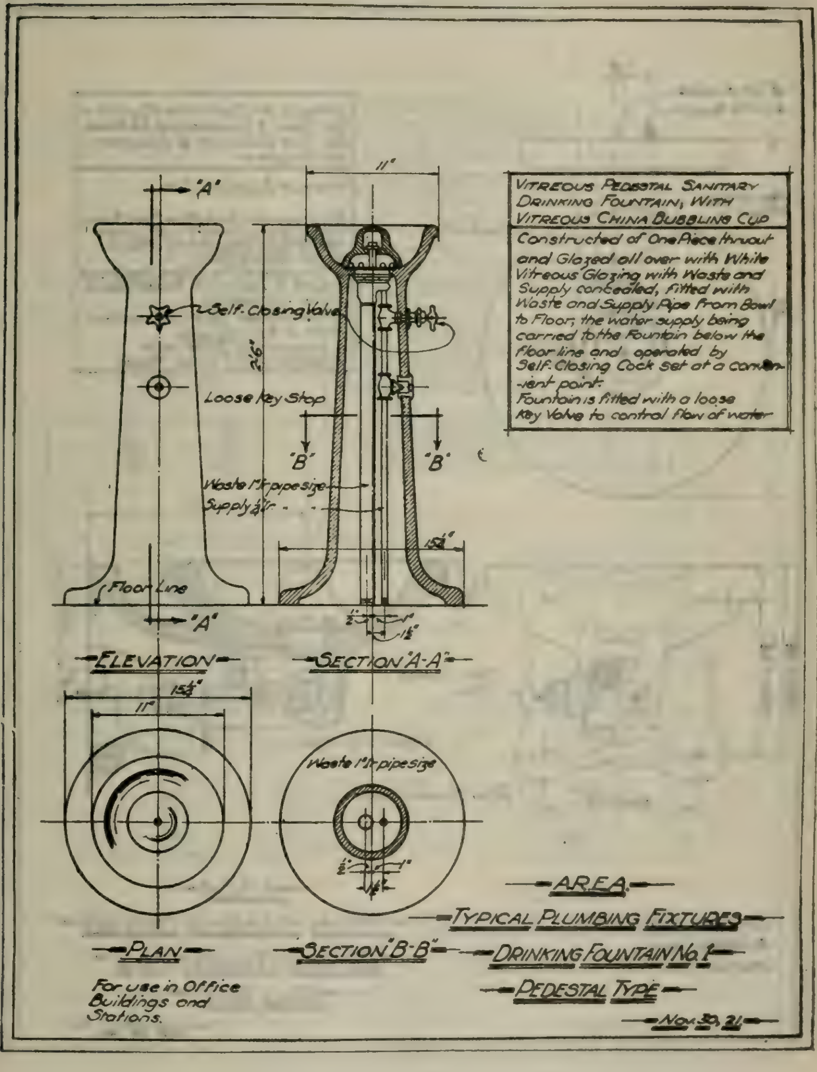
TYPICAL PLUMBING FIXTURES

URINAL No. 4

SYPHON JET VITREOUS TYPE

Nov. 30, '21

For use in Freight Offices, Freight Rooms, Shops, and less important Stations.



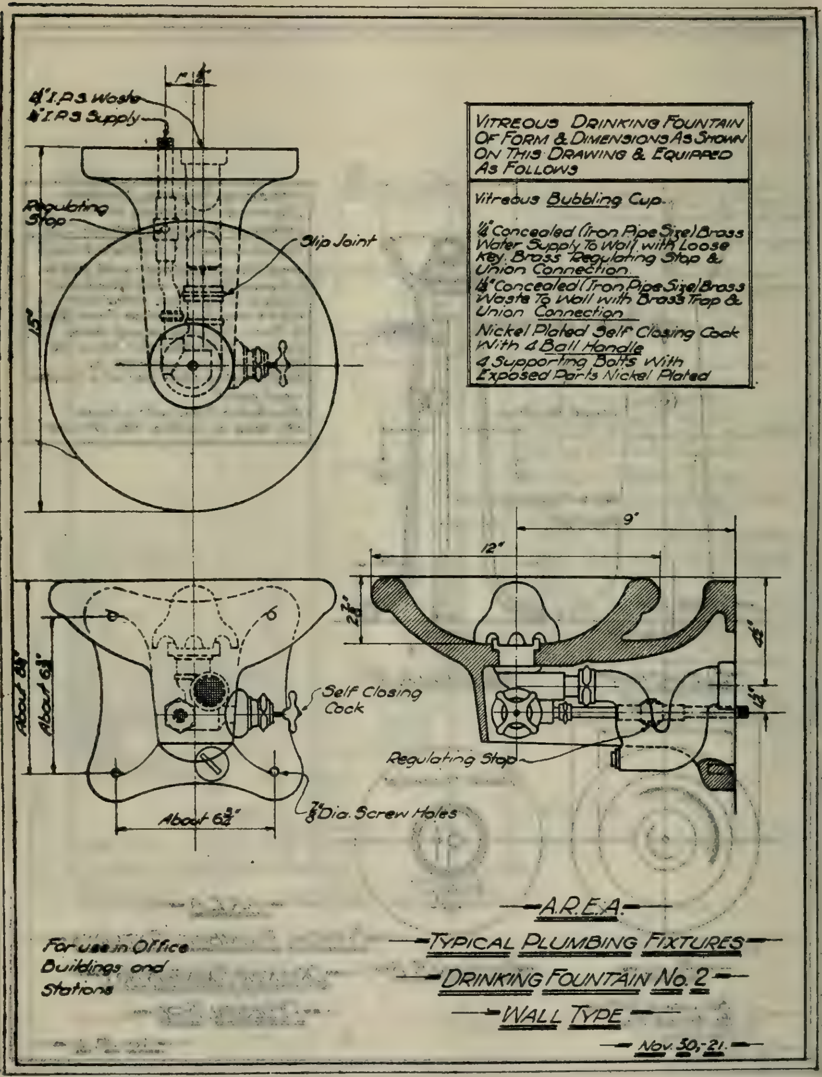
VITREOUS PEDESTAL SANITARY DRINKING FOUNTAIN, WITH VITREOUS CHINA BUBBLING CUP

Constructed of One Piece thruout and Glazed all over with White Vitreous Glazing with Waste and Supply concealed, fitted with Waste and Supply Pipe from Bowl to Floor; the water supply being carried to the Fountain below the floor line and operated by Self-Closing Cock set at a convenient point.

Fountain is fitted with a loose Key Valve to control flow of water

For use in Office Buildings and Stations.

AREA.
TYPICAL PLUMBING FIXTURES
DRINKING FOUNTAIN No. 1
PEDESTAL TYPE
Nov. 30, 21



VITREOUS DRINKING FOUNTAIN OF FORM & DIMENSIONS AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS

Vitreous Bubbling Cup.

¼" Concealed (Iron Pipe Size) Brass Water Supply To Wall with Loose Key. Brass Regulating Stop & Union Connection.

¼" Concealed (Iron Pipe Size) Brass Waste To Wall with Brass Trap & Union Connection

Nickel Plated Self Closing Cock With 4 Ball Handle

4 Supporting Bolts With Exposed Parts Nickel Plated

For use in Office Buildings and Stations

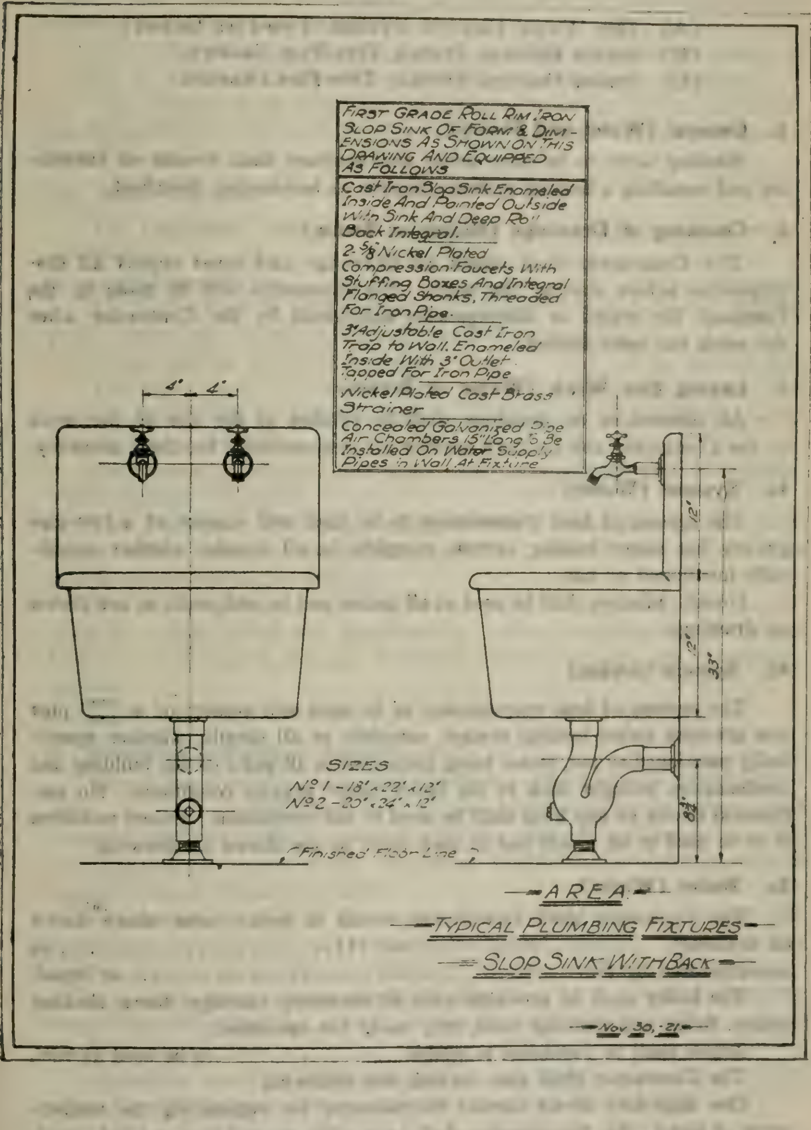
A.R.E.A.

TYPICAL PLUMBING FIXTURES

DRINKING FOUNTAIN No. 2

WALL TYPE

Nov. 30, -21.



First Grade Roll Rim Iron Slop Sink Of Form & Dimensions As Shown On This Drawing And Equipped As Follows

Cast Iron Slop Sink Enameled Inside And Painted Outside With Sink And Deep Roll Back Integral.

2-⅝ Nickel Plated Compression Faucets With Stuffing Boxes And Integral Flanged Shanks, Threaded For Iron Pipe.

3" Adjustable Cast Iron Trap to Wall. Enameled Inside With 3" Outlet Tapped For Iron Pipe

Nickel Plated Cast Brass Strainer

Concealed Galvanized Pipe Air Chambers 15" Long To Be Installed On Water Supply Pipes in Wall At Fixture

SIZES
Nº 1 – 18" × 22" × 12"
Nº 2 – 20" × 24" × 12"

AREA

Typical Plumbing Fixtures

Slop Sink With Back

Nov 30, -21

Section 19-A-B-C

[33]HEATING

(A) Hot Water Heating System, Two-Pipe Gravity.
(B) Steam Heating System, One-Pipe Gravity.
(C) Steam Heating System, Two-Pipe Gravity.

1. General (Water and Steam)

Heating work to be done under this contract shall consist of furnishing and installing a heating system complete as hereinafter described.

2. Checking of Drawings (Water or Steam)

The Contractor shall check all drawings and must report all discrepancies before starting the work. No allowances will be made by the Company for errors or discrepancies discovered by the Contractor after the work has been started.

3. Laying Out Work (Water or Steam)

All dimensions on drawings shall be verified at the site of the work by the Contractor and he shall assume all responsibility for their accuracy.

4a. System (Water)

The system of heat transmission to be used will consist of a two-pipe gravity hot water heating system, complete in all details, whether specifically mentioned or not.

Direct radiation shall be used at all points and in such units as are shown on drawings.

4b. System (Steam)

The system of heat transmission to be used will consist of a $\frac{\text{one-}}{\text{two-}}$ pipe low pressure steam heating system, complete in all details, whether specifically mentioned or not, steam being circulated to all parts of the building and condensation brought back to the boiler under gravity conditions. No mechanical device of any kind shall be used to aid circulation. Direct radiation is to be used at all points and in such units as are shown on drawing.

5a. Boiler (Water)

The Contractor shall furnish and install in boiler room where shown on drawing........................one (1)........................., as manufactured by the...or equal.

The boiler shall be provided with all necessary castings, doors, shaking grates, firing and cleaning tools, etc., ready for operation.

Grates shall be furnished to enable..................to be used as fuel.

The Contractor shall also furnish the following:

One high-duty direct contact thermometer for registering the temperature of water; this thermometer shall have white enamel face and red liquid. One altitude gage for registering the proper height of the water in the expansion tank.

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[33] Adopted, Vol. 27, 1926, pp. 1179, 1421.

One "Syphon" water regulator or equal of required size for correct temperature control.

The Contractor shall also make necessary connection to the water supply where found in the building and shall provide draw-off valves to enable the system to be drained.

The boiler shall be covered with a covering of approved make, as outlined in Article 17 of these specifications, unless otherwise specified.

This boiler is to be tested for any defects in castings before any covering is applied. Boiler shall be installed in accordance with manufacturer's specifications.

5b. Boiler (Steam)

The Contractor shall furnish and install in boiler room where shown on drawing.................. one (1).. as manufactured by the...or equal.

The boiler shall be provided with all necessary castings, doors, shaking grates, firing and cleaning tools, etc., ready for operation.

Grates shall be furnished to enable.....................to be used as fuel.

The boiler shall be furnished with approved type of steam gage with syphon safety valve of sufficient capacity to take care of boiler, also water gage and gage cocks.

For correct regulation, this boiler shall be equipped with a "Syphon" steam regulator or equal.

The Contractor shall also make necessary connection to the water supply where found in the building, and shall provide draw-off valves to enable the system to be drained.

The boiler shall be covered with a covering of approved make as outlined in Article 17 of the specifications, unless otherwise specified. The boiler is to be tested for any defects in castings before any covering is applied.

Boiler shall be installed according to manufacturer's specifications.

6. Breeching (Water or Steam)

The boiler shall be connected to chimney by a smoke breeching of No...............gage black iron, provided with necessary dampers and cleanout openings. These cleanout openings shall be of ample size and they shall be so arranged that the entire length of the breeching can be cleaned without dismantling same.

The breeching shall be of the required size and shall be painted both inside and outside with two coats of asphaltum varnish. This breeching shall be covered as specified in Article 17 of these specifications.

The Contractor shall support this breeching in a substantial manner. Where the breeching enters the chimney, it shall be increased in area at least 10 per cent.

Breeching shall be installed in such a manner as to maintain a minimum distance between nearest wall and breeching of 18 inches.

7a. Piping System (Water)

The system of piping to be used in this installation shall be what is known as a two-pipe system with $\substack{\text{basement}\\\text{overhead}}$ supply main and $\substack{\text{up}\\\text{down}}$ feeds to all radiators. All piping is to be supported in a substantial manner.

Whenever possible, the piping is to be arranged in such a manner that the first radiator on the supply circuit will be the last on the return circuit. The system shall be provided with vents and drains at all points where required.

The supply and return piping is to be arranged in such a manner as to allow for proper circulation to all parts of the system without crowding or forcing.

All piping exposed in the building, with the exception of that in the boiler room, and where same is subjected to low temperatures, shall remain uncovered. All piping not exposed to public view, where located in the boiler room, attic space, basement, concealed in walls, or exposed to low temperatures, shall be covered, as outlined in Article No. 16 of these specifications. Piping is to be concealed unless otherwise specified. Concealed piping is to be tested for leaks and defects before covering is applied.

The Contractor shall ream the ends of all pipes used in connection with this installation, so that the flow will not be restricted.

No control valves are to be installed on supply or return mains or radiators, unless otherwise specified. Radiators requiring venting shall be equipped with air valves of the lock and shield compression type.

7b. Piping System (Steam)

The system of piping to be used in this installation shall be a $\substack{\text{one-}\\\text{two-}}$ pipe system with $\substack{\text{overhead}\\\text{basement}}$ supply main and $\substack{\text{down}\\\text{up}}$ feeds to all radiators. All piping is to be supported in a substantial manner.

The system is to be provided with vents and drips at all points where required.

Care shall be taken when laying out piping system, that the condensation shall flow in the same direction as the steam and the use of a wet return to the boiler is to be avoided wherever possible.

The piping is to be arranged in such a manner as to allow for proper circulation to all parts of the system without crowding or forcing.

All piping exposed in the building, with the exception of that in the boiler room and where subjected to low temperatures, shall remain uncovered. Piping not exposed to public view, where located in boiler room, attic space, basement, concealed in walls or exposed to low temperatures, shall be covered as outlined in Article 16 of these specifications. The Contractor shall ream the ends of all pipes used in connection with this installation so that the flow will not be restricted.

Steam shall be taken from the boiler into a main leader and circulated through the building by means of supply mains. At each point where a supply main is taken off the main header, a control valve shall be installed.

Returns shall be brought back to a manifold header, which in turn shall be connected to the boiler. At each point where a return main is connected to the manifold header, a control valve shall be installed.

At the end of each supply and return main or where same drops to a lower level, an automatic vent shall be installed so located that it can be inspected.

All concealed piping is to be tested for leaks and defects before covering is applied.

8. Expansion Tank (Water)

The Contractor shall furnish and install in the most suitable location, or as indicated on drawing, one..........Expansion Tank.......... gallons capacity.

Expansion tank shall be properly vented, care being taken that vent is installed in such a manner as to prevent syphonage.

The expansion pipe shall be connected to the return main in the most suitable location.

The overflow pipe from the expansion tank shall be installed so that it will discharge to the drain in the boiler room.

Expansion tank is to be arranged so that it will be circulating if deemed necessary.

All necessary supports, piping, valves and connections for expansion tank are to be provided and installed by the Contractor.

9. Radiators (Steam or Water)

All radiators used in connection with this installation shall be of the following type according to location in which placed.

Floor pattern...or equal.
Wall pattern...or equal.

The Contractor shall state make of radiators he proposes to furnish and no substitution will be allowed from that mentioned in proposal.

10. Hangers for Radiators (Steam or Water)

All radiators of wall pattern shall be so supported as to thoroughly take care of expansion and contraction by means of the................. hanger as made by...

The hangers shall be fastened to the walls in their respective locations by heavy expansion bolts firmly secured in the walls.

Should the design of the trim of the building be such that hangers cannot be fastened directly to the walls, the Contractor shall provide the necessary material to install hangers. Lumber used for this purpose shall conform to the trim of the building in all respects and be of neat finish.

11. Location of Radiators (Water or Steam)

The location of the radiators as shown on the drawing shall be construed as being approximately correct. Should conditions at the building prove such as to make any changes necessary in the location of the radiators, from that shown on the drawing, such change shall not alter price agreed upon in contract.

12. Connections to Radiators (Water or Steam)

All connections to radiators shall be taken from the $\overset{\text{bottom}}{\text{top}}$ of the supply main by 45 degree fittings and the distance between the supply main and the center of the radiator connections and shall not be less than 30 inches. All return connections from the radiators shall be taken in at the side or top of the return main.

13a. Valves on Radiator (Water)

Radiator control valves when specified, shall be on return connection of radiator only.

Valves to be used shall be what are known as the quick operating water radiator valves, with a $\frac{1}{16}$ inch hole drilled in the conical shell, to allow for a slight circulation in the event the valve is closed and thus prevent a possible freezing of the radiator. All valves shall have rough body and nickel plated trimmings equipped with union connections and hard wood handle unless otherwise specified.

Air valves are to be installed on radiators where required and shall be of the lock and shield compression type.

The Contractor shall state make of radiator and air valves he proposes to install and no substitution will be allowed from that mentioned in proposal. Each radiator is to be equipped with a valve of approved make, on flow and return.

13b. Valves on Radiator (Steam, One-Pipe)

Each radiator shall be equipped with a valve of approved make. Valves shall be of radiator type and with rough body and nickel trimmings, union connections and hardwood handles, unless otherwise specified. Valves shall be equipped with hard rubber disc of .... make or equal.

Each radiator and points of the system requiring venting shall be equipped with automatic non-adjustable air valves of approved make.

The Contractor shall state make and type of radiator and automatic air valves he proposes to furnish and no substitution will be allowed from that mentioned in proposal.

13c. Valves on Radiator (Steam, Two-Pipe)

Valves shall be of radiator type with rough body, nickel plated trimmings, union connections and hardwood handles, unless otherwise specified.

Valves shall be equipped with hard rubber disc of .... make or equal.

Each radiator and point of the system requiring venting are to be equipped with non-adjustable automatic air valves of approved make.

The Contractor shall state make and type of radiator and automatic air valves he proposes to furnish and no substitution will be allowed from that mentioned in proposal.

14. Support for Pipe (Water or Steam)

All piping shall be firmly and neatly secured with proper provision for expansion and contraction. The horizontal lines shall be hung on neat trapez expansion hangers placed at proper intervals while all other lines shall be provided with suitable hangers, best adapted to the existing conditions to make a good appearing and substantial job.

Anchors shall be placed at points on lines to take care of the expansion from central points to ends. The use of perforated bar or strap hanger will not be permitted.

The Contractor when submitting his layout for approval, shall submit details of all hangers for the approval of the Engineer.

15. Expansion and Contraction (Water or Steam)

The expansion and contraction of all supply and return mains must be taken care of in the design of the system. The use of the mechanical slip joint will not be permitted in connection with this installation.

16. Material to Be Used (Water or Steam)

All pipe used in connection with this installation shall be new, strictly genuine wrought iron pipe as made by the...or equal.

Valves shall be of type made by..............................or equal.

Fittings shall be of fine grained grey cast iron......................... make or equal, with threads clean cut, tapering and smooth.

Thread joints shall be iron to iron without the use of red lead or cement, all flanged fittings shall be made with...................padding or gaskets or equal.

Unions shall be of the Railroad pattern, metal to metal, no gaskets shall be used.

On all pipe lines 3 inches and up, flanged fittings shall be used and below that threaded fittings shall be used.

All materials used in connection with this installation shall be the best of their respective kind, and be put together by skilled mechanics under competent supervision.

All piping to be insulated in connection with this heating system shall be covered with..................covering as made by the.................................or equal.

This pipe covering shall be of standard thickness with metal bands at ends and center of sections. Fittings shall be covered with plastic material of quality described below and shall also have canvas jackets. All piping installed underground shall be covered and encased in conduits as called for.

No covering is to be applied on any piping exposed in portion of building used by public unless otherwise specified.

The Contractor shall state make and grade of covering he proposes to furnish and no substitutions will be allowed from that mentioned in proposal.

17. Plastic Covering (Water or Steam)

The boiler and smoke breeching in the boiler room shall be provided with a plastic asbestos covering of the above make, unless otherwise specified. This plastic covering shall be applied first in the form of asbestos blocks 1½ inches thick and then with ½ inch thick hard finish of asbestos cement, neatly secured in place, followed by a canvas jacket neatly pasted on.

The covering on the smoke breeching shall be in the form of one inch asbestos blocks applied on ½ inch mesh black iron wire cloth with one inch "V" iron attached to form air space and fastened directly to the iron, with finishing coat of cement followed by canvas jacket neatly pasted on.

18. Insulation Through Walls, Floors and Partitions (Water or Steam)

Where pipes pass through floors or run through partitions galvanized iron sleeves with proper air space between the walls of the sleeves and the pipes shall be placed. Where they pass through bearing walls, sleeves of wrought iron pipe shall be used with proper provision for air space. At all points where sleeves are used, proper nickel plated floor and ceiling plates shall be used.

The Contractor shall pay special attention that there shall be no ragged holes appearing where any pipes pass through walls or floors.

19a. Guarantee (Water)

The Contractor must guarantee the perfect operation of the system as heretofore described and indicated on drawings and that it will be capable of warming the rooms in the building to the following temperatures, with the temperature of the water in the radiators not to exceed 170 degrees Fahr.

Room	*Outside Temperature*	*Inside Temperature*
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

He must guarantee also that it will circulate freely, without crowding or forcing, to all parts of the system, and should any defects appear in same within the course of one year of actual operation, the Contractor shall make good such defects at his own expense.

If in the opinion of the Contractor the amount of radiation and size of boiler as set forth on the drawings is not sufficient to fulfill his guarantee, he shall state in his proposal the amount of additional radiation and additional boiler capacity which in his judgment is necessary and quote prices for same.

Any omissions in these specifications or the drawings accompanying same, do not relieve the Contractor of his obligation to install the system complete in every respect to fulfill his guarantee.

19b. Guarantee (Steam)

The Contractor must guarantee the perfect operation of the system heretofore described and indicated on drawing, that it will be capable of warming the rooms in the building to the following temperatures with a steam pressure of from two to five lb. per square inch by gage on the boiler and a drop in pressure in the piping not to exceed 8 ounces.

Room	*Outside Temperature*	*Inside Temperature*
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

He must guarantee also that it will circulate freely to all parts of the system without crowding or forcing, and should any defects appear in the same within the course of one year of actual operation, the Contractor shall make good such defects at his own expense.

If in the opinion of the Contractor, the amount of radiation and size of the boiler as set forth on the drawing, is not sufficient to fulfill his guarantee, he shall state in his proposal the amount of additional radiation and additional boiler capacity which in his judgment is necessary and quote prices for same.

Any omissions in these specifications or on the drawings accompanying same, do not relieve the Contractor of his obligations to install the system complete in every respect and fulfill his guarantee.

The minimum amount of direct radiation which will be acceptable in the building will be...........square feet.

If the Contractor considers it necessary to deviate from the drawings in order that his guarantee may be fulfilled, he may do so only upon the written permission from the Engineer.

20. Preliminary Tests and Cleaning (Water or Steam)

The Contractor shall make a thorough test of the plant to ascertain whether there are any leaks in the boiler, piping, etc., after completion, he shall also arrange to remove all sediment, rust and dirt out of the system. In order to do this, the boiler is to be operated for a period of not less than 24 hours and during this operation, the boiler is to be blown off frequently until the water blown down from the boiler is reasonably clear.

21. Test (Water or Steam)

Upon notification from the Contractor, the Company shall within two weeks, make a test of the complete system, and it will be accepted only after test is satisfactory to the Company, all leaks and defects have been repaired and all conditions of these specifications have been fully and satisfactorily complied with. The Contractor shall furnish a complete set of written instructions neatly framed and glazed, covering the operation of the plant for reference purposes.

22. Completion (Water or Steam)

At the completion of the installation and its acceptance by the Company, the Contractor must give instructions as to the operation of the plant, showing in detail all points that require attention and turn same over to the Company. He shall also furnish for the Company's file, one complete set of ink tracings or VanDyke negatives on cloth made from ink tracings, showing in detail the complete installation.

23. Cleaning (Water or Steam)

At the completion of the work, the Contractor shall remove all construction equipment, scaffolding, staging, erection platforms, and all surplus material from the premises, leaving the building in a clean and acceptable condition. If any equipment, material or debris is not removed with sufficient promptness, the Company may remove it at the expense of the Contractor.

24. General Conditions (Water or Steam)

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed, and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 19-D

[34]HOT AIR HEATING

1. General

The Contractor shall furnish all labor, material, tools and equipment, except as otherwise noted, to entirely complete the heating work as specified or shown on drawings.

2. Furnace

The Contractor shall furnish, set up and properly connect, where shown on the drawings, ... No. .... Furnace (s), as manufactured by .... or equal, equipped with .... control. Furnace shall be provided with all necessary castings, doors, shaking grates, firing and cleaning tools, waterpan, etc., ready for operation; grates shall be furnished to enable .... to be used as fuel.

3. Smoke Pipe

The smoke pipe is to be .... inches in diameter, of .... gage galvanized steel, properly fastened in place, and equipped with a tight damper and check-draught. Woodwork within 18 inches of smoke pipe shall have a protection at least 30 inches wide of ¼ inch asbestos board with 2 inch open air space between the protection and the woodwork, or otherwise meet requirements of local building code.

4. Supply Pipes and Register Boxes

The Contractor shall furnish and install all necessary pipes and register boxes to properly heat the building and they shall be made of tin of .... U.S. gage; all joints shall be made tight. Each supply pipe shall be equipped with a control damper adjacent to the furnace. The pitch of all supply pipes shall be such that the flow of air will circulate freely to all parts of the system without being forced. Supply pipes, register boxes and register faces shall be of ample size to permit the proper amount of air being delivered to the room and the registers shall have sufficient free area and be designed to be shut-off at will.

5. Insulation

The outside jacket of the furnace and all supply piping or hot air pipes shall be properly insulated with .... ply asbestos paper.

6. Return Air Pipes

The Contractor shall furnish and install return air pipes and inlet boxes equipped with a register of sufficient size to provide proper circulation. The return pipes shall enter the furnace at its base.

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[34] Adopted, Vol. 27, 1926, pp. 1187, 1421.

7. Openings

All openings are to be cut true, and not more than ¼ inch larger than the dimensions of the register boxes to be used. The Contractor shall pay special attention that there shall be no ragged holes appearing where registers are installed.

8. Register Faces

The Contractor shall furnish and install register faces or grilles of approved design and pattern, and set and fit same in place. Contractor shall state in his proposal size and type of register faces or grilles he proposes to furnish and install in the various rooms.

9. Guarantee

The Contractor must guarantee the perfect operation of the system as heretofore described, that it will be capable of heating the rooms in the building to the following temperatures:

Room	*Outside Temperature*	*Inside Temperature*
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

The Contractor shall state sizes of supply pipes leading to each room, free area of register faces, size of return pipes, also any other information having any bearing on design of system, and shall guarantee the same to circulate freely, without crowding or forcing, to all parts of the system and should any defects appear in same within the course of one year of actual operation, the Contractor shall make good such defects at his own expense. Any omissions in these specifications or the drawings accompanying same, do not relieve the Contractor of his obligation to install the system complete in every respect to fulfill his guarantee.

10. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 19-E

[35]HOT BLAST HEATING SYSTEM

1. General

The Contractor shall furnish all labor, materials, tools and equipment, except as otherwise noted, to entirely complete the heating work as hereinafter specified or shown on drawings.

2. Checking Drawings

The Contractor shall check all drawings and must report all discrepancies before starting the work. No allowances will be made by the Company for errors or discrepancies discovered by the Contractor after the work has started.

3. Laying Out Work

All dimensions on drawings shall be verified at the site of the work by the Contractor, and he shall assume all responsibility for their accuracy.

4. System

The system of heat transmission to be used will consist of a hot blast or blower system, complete in all details, whether specifically mentioned or not.

The hot air is to be distributed to the different parts of the building by means of a fan driven by a steam engine or electric motor, through a system of air ducts as shown on drawings.

Steam to be used in the heater shall be exhaust or live steam at reduced pressure according to local conditions.

Condensation from the heater shall be returned to boiler plant by means of a vacuum pump.

5. Steam Supply Lines to Heater and Engine

The steam supply for the heater shall be obtained from the point shown on drawings.

Where exhaust steam is used in the heater, the Contractor shall make connections to existing exhaust mains, of points shown on drawings, install an oil separator, if necessary, and then carry piping from the source of supply to the steam header of the heater in the heater room.

In order to insure an adequate supply of steam when exhaust steam is used, the Contractor shall provide a high pressure steam connection with pressure reducing valve, so arranged as to open and admit steam into the exhaust steam supply main when there is insufficient exhaust steam to supply the heater.

When live steam at reduced pressure is used in the heater, the Contractor shall make connections to high pressure steam main where shown on drawings, install a pressure reducing valve, and carry piping to steam header of heater.

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[35]Adopted, Vol. 27, 1926, pp. 1189, 1421.

Where a steam engine is used for operating the fan the steam supply for this engine shall be obtained from the high pressure steam line where indicated. This steam line shall be of required size to supply sufficient steam to operate the engine.

6. Return Mains and Drips from Exhaust Steam Main

The return line from the heater shall be connected to the vacuum pump, which shall be located where indicated on drawing.

All drips taken from the exhaust header shall be connected to the return line in a suitable manner.

7. Exhaust Connections for Summer Use

In case it is desired to use the blower system in the building as a ventilating medium during the summer months, the Contractor shall provide for the diversion of the exhaust steam from the fan engine to the atmosphere. This exhaust pipe shall be provided with a back pressure valve, also an exhaust head, both of which shall be of .... make, or equal; this exhaust head shall be of cast iron.

8. Vacuum Pump and Specialties

The Contractor shall furnish and install in the location indicated on the drawings .... vacuum pump(s), complete in all details including suction strainer and all specialties.

This pump shall be of .... pattern .... x .... size of .... Company's make, or equal.

The pump shall be equipped with a cast iron drip pan with all drains properly connected to existing sewers.

This pan shall be set on a concrete foundation 12 inches above the floor level. Foundation bolts and foundation shall be provided by the Contractor.

The pump shall be equipped with a mechanical oil pump of sufficient size of .... make, or equal. The oil pump shall be applied at the factory.

The steam for this (these) pump(s) shall be taken from the location indicated on the drawings, and the exhaust shall be connected to the exhaust main.

The discharge from this (these) pump(s) shall be connected as indicated on the drawings, or as directed by the Engineer.

Pump(s) shall be controlled by a governor of .... make, or equal; governor shall be by-passed to enable pump(s) to be operated by hand in the event the governor becomes inoperative.

All piping, fittings, valves, gages, etc., required to connect the pump to the heating system and discharge the condensation to the boiler plant and place same in proper operation, shall be furnished and installed by the Contractor.

9. Air Ducts

All metal air ducts installed in connection with this work shall be furnished and installed by this Contractor, but any air ducts other than metal will be provided by others.

10. Radiation in Heater

The heating unit used in connection with this installation shall be a .... heater as manufactured by the .... Company, or equal. The heater shall contain .... sq. ft. of radiation, arranged to suit the requirements under which the heater is to operate. Steam to be used in the heater shall not exceed 3 lb. per sq. in. gage pressure. Each stack of the heater is to be controlled independently by a control valve.

All necessary piping, fittings, valves, specialties, etc., required for the correct installation and operation of the heater shall be furnished and installed by the Contractor.

11. Vacuum Traps

The vacuum system specialties, which in this case refer principally to the style of trap used on the return connections from the heater, shall be those made by the .... Company, or equal.

All necessary specialties required to connect the heater to the vacuum system shall be furnished and installed by the Contractor.

12. Heater Casing

The heater casing and connection to fan inlet shall be of No. .... gage black iron, reinforced with angle and tee iron shapes designed in accordance with drawing No. ....

13. Fan

The fan to be used in this installation shall be of multiblade type, of Size No. ...., Design No. ...., of .... Company's make, or equal.

This fan is to be directly connected to steam engine by coupling of the "safety" flange type with concealed bolt heads and nuts.

The fan is to be equipped with runner of .... inches diameter and is to be operated at a peripheral speed of .... feet per minute. It is to be of $\left\{\begin{matrix}\text{single}\\ \text{double}\end{matrix}\right\}$ inlet .... housed, $\left\{\begin{matrix}\text{single}\\ \text{double}\end{matrix}\right\}$ width, ... discharge, with approximate capacity of .... cu. ft. per minute at .... static pressure.

14. Steam Engine

Where a steam engine is used the fan is to be driven by direct connected $\left\{\begin{matrix}\text{vertical}\\ \text{horizontal}\end{matrix}\right\}$ steam engine operating at .... revolutions per minute, with a steam pressure not exceeding .... lb. per sq. in. at the engine throttle. This engine is to operate against a back pressure of 5 lb. per sq. in., and it is to be provided with a steam separator governor, and all necessary lubricating devices, of approved make.

The engine installed shall be of sufficient capacity to develop at least 50 per cent overload.

The exhaust steam from engine is to be passed through an oil separator and utilized in the heater. All drips from the engine and oil separators shall be connected to a blowoff basin, which shall also be furnished and installed by the Contractor.

All necessary piping, fittings, valves, traps, etc., required for the correct installation of the steam engine shall be furnished and installed by the Contractor.

15. Foundation and Trenches

The Contractor shall furnish and install all necessary foundations, foundation bolts, trenches, wells, checkered plate covers, etc., required for the installation of the heater, fan and fan engine.

16. Motor

When the electric drive is used, the fan is to be driven by a

$$\begin{matrix}\text{Constant speed}\\ \text{Variable speed}\end{matrix}\left\{\begin{matrix}\text{direct driven}\\ \text{belt driven}\\ \text{silent chain}\\ \text{driven}\end{matrix}\right\}\text{electric motor of}\left\{\begin{matrix}\text{squirrel cage}\\ \text{slip ring}\end{matrix}\right.$$

type of .... Company's make, or equal.

This motor shall be of .... H.P. at a speed of .... r.p.m., and it shall be designed not to exceed a maximum rise in temperature of 40 degrees Cent. above the surrounding atmosphere, after a continuous operation under full load for 2 hours.

The starter or controller to be used in connection with this motor shall be of the .... Company's make, or equal.

All electrical connections between the motor and starter, or controller, shall be furnished and installed by the Contractor, but all other connections between starter, or controller, and service box will be made by others.

All electrical equipment used in connection with the work shall be designed to suit .... volt .... phase .... cycles $\left\{\begin{matrix}\text{direct}\\ \text{alternating}\end{matrix}\right\}$ current, and shall conform to the rules and regulations of the National Board of Underwriters, and shall be subject to the approval of the Electrical Engineer of the Railway Company.

The motor shall be provided with a $\left\{\begin{matrix}\text{sliding}\\ \text{solid}\end{matrix}\right\}$ base, and shall be securely bolted to a suitable foundation.

17. Pressure Reducing Valves

Pressure reducing valves shall be of .... make, or equal. Each valve shall be by-passed. The valve on by-pass shall be of lock and shield pattern, to prevent it from being opened by unauthorized persons.

The pressure reducing valve is to be provided with a safety valve on low pressure side. Safety valve shall be set at .... lb. per sq. in. pressure.

The Contractor shall also furnish necessary pressure gage and connections with each valve, and pipings, fittings, valves, etc., to properly install pressure reducing valve.

18. Steam Traps

Steam traps shall be of .... make, or equal. They shall be by-passed and suitable for the service in which they are installed.

All necessary piping, fittings, valves, etc., required for the correct installation of steam traps shall be furnished and installed by the Contractor.

19. Oil Separators

Wherever a connection is made to an exhaust steam line for heating purposes, the Contractor shall furnish and install an oil separator at the point where such connection is made.

Oil separators shall be of the .... Company's make, or equal, and suitable for the service for which they are installed.

Each separator is to be drained through an oil trap of required size. The oil trap shall be by-passed so that the separator may be drained directly through the oil trap to blowoff basin.

Place oil traps on floor at lowest possible point, with check valve in horizontal connection to trap.

20. Overhead Pipe Supports

Any overhead mains outside the building shall be supported on adequate pipe supports set on concrete bases. These supports shall be of required strength to support the sizes of piping carried, and they shall be designed so as to allow the pipe to expand and contract.

They shall be spaced so as to prevent sag in the pipe line, with a minimum clearance under pipe line of 22 feet above top of rail.

21. Supports for Pipes

All piping shall be firmly and neatly secured, with proper provision for expansion and contraction. The horizontal lines shall be supported on neat trapeze expansion hangers at proper intervals, while all other lines shall be provided with suitable hangers best adapted to the existing conditions, to make a good appearing and substantial job.

Anchors shall be placed at points on lines to take care of the expansion from central points to the ends. The use of perforated bar or strap hanger will not be permitted.

The Contractor, when submitting his layout for approval, shall submit details of all hangers for the approval of the Engineer.

22. Underground Conduit and Insulation

Where steam and return piping are run underground, they shall be installed in a waterproof conduit, preferably of the culvert or open type, equipped with interior drain, similar in design to the .... Company's make, or equal.

The conduit shall be built complete with necessary expansion and anchor pits, and drain connection to the nearest sewer at the low end. The minimum distance between the top of the conduit and the ground level shall be ...., and the floor of the conduit shall be graded to secure a good runoff for drainage. Material excavated to enable conduit to be constructed shall be used as backfill.

Concrete used in the construction of this conduit shall be in accordance with A.R.E.A. Specifications, of .... mixture, and all other materials shall be of standard grades of approved make.

All piping installed in conduit shall be insulated with pipe covering of make specified in paragraph "Materials to Be Used."

Insulation used on high pressure steam mains shall be "...................." covering, of .... thickness.

Insulation used on low pressure steam mains shall be "..............." covering, of .... thickness.

Insulation shall be installed as specified, and shall be painted with two coats of waterproof paint.

23. Expansion and Contraction

The expansion and contraction of all supply and return mains must be taken care of in the design of the system.

24. Material to Be Used

All pipe used in connection with this installation shall be new, strictly genuinely wrought iron pipe, as made by the ...., or equal.

Valves shall be of the type made by .... or equal.

Fittings shall be of fine grained grey cast iron, ... make, or equal, with threads clean cut, tapering and smooth.

Thread joints shall be iron to iron without the use of red lead or cement. All flanged fittings shall be made with .... padding or gaskets, or equal. Unions shall be of the Railroad pattern, metal to metal, no gaskets shall be used.

On all pipe line 3 inches and up, flanged fittings shall be used, and below that size threaded fittings shall be used.

All materials used in connection with this installation shall be the best of their respective kinds, and shall be put together by skilled mechanics under competent supervision.

All piping to be installed in connection with this heating system shall be covered with .... covering, as made by the .... or equal. This pipe covering shall be of standard thickness, with metal bands at ends and center of sections. Fittings shall be covered with plastic material of quality described below, and shall also have canvas jackets.

All piping installed underground shall be covered and encased in conduits as called for.

All overhead outside piping shall be covered with double thickness covering of the above mentioned quality, same to be equipped with an approved weatherproof jacket.

No covering shall be applied to any piping until the pipe lines have been tested.

The Contractor shall state make and grade of covering he proposes to furnish, and no substitutions will be allowed from that mentioned in his proposal.

25. Insulation Through Walls, Floors and Partitions

Where pipes pass through floors or run through partitions, galvanized iron sleeves, with proper air space between the walls of the sleeve and the pipes, shall be used. Where they pass through bearing walls, sleeves of wrought iron pipe shall be used with proper provision for air space. At all points where sleeves are used, proper nickel plated floor and ceiling plates shall be provided. Contractor shall pay special attention so that there will be no ragged holes appearing where any pipes pass through walls or floors.

26. Guarantee

The Contractor shall guarantee the perfect operation of the system described above and indicated on the drawings, that it will be capable of warming the building to .... degrees Fahrenheit temperature when the outside temperature is .... degrees, with a steam pressure of from 2 lb. to 5 lb. per sq. in. by gage in the heater, and also that it will circulate freely to all parts of the system without crowding or forcing. Should any defects appear in the system within the course of one year of actual operation, the Contractor shall make such defects good at his own expense.

If, in the opinion of the Contractor, the amount of radiation in the heater, size of fan and steam engine, as set forth on the drawings, is not sufficient to fulfill his guarantee, he shall state in his proposal the amount of additional radiation in heater, size of fan and steam engine, which, in his judgment, is necessary, and quote prices for same.

The minimum amount of direct radiation which will be acceptable in the heater will be .... sq. ft.

Any omissions in these specifications or on the drawings accompanying same, do not relieve the Contractor of his obligations to install the system complete in every respect and fulfill his guarantee.

If the Contractor considers it necessary to deviate from the drawings in order that his guarantee may be fulfilled, he may do so only upon the written permission of the Engineer.

27. Preliminary Tests and Cleaning

The Contractor shall make a thorough test of the plant to ascertain whether there are any leaks in the heater, piping, etc., after completion. He shall also arrange to remove all sediment, rust and dirt out of the system. In order to do this, the heater is to be operated for a period of not less than 24 hours, and during this operation all condensation from the heater is to be discharged directly into the sewer.

28. Tests

Upon notification from the Contractor, the Company will, within two weeks, make a test of the complete system, and it will be accepted only after test is satisfactory to the Company, all leaks and defects have been repaired, and all conditions of these specifications fully and satisfactorily complied with. The Contractor shall furnish a complete set of written instructions, neatly framed and glazed, covering the operation of the plant, for reference purposes.

29. Completion

At the completion of the installation and its acceptance by the Company, the Contractor must give instructions as to the operation of the plant, showing in detail all points that require attention, and turn same over to the Company. He shall also furnish for the Company's file one complete set of ink tracings or VanDyke negatives, on cloth, made from ink tracings, showing in detail the complete installation.

30. Cleaning

At the completion of the work, the Contractor shall remove all construction equipment, scaffolding, staging, erection platforms and all surplus material from the premises, leaving the building in a clean and acceptable condition. If any equipment, material or debris is not removed with sufficient promptness, the Company may remove it at the expense of the Contractor.

31. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions, as given in Section 1 of this specification, shall be considered to apply with equal force to this section of the specification.

Section 20

[36]ELECTRIC LIGHT WIRING

1. General

The Contractor shall furnish all labor, material, tools and equipment necessary to entirely complete and install any and all kinds of electric light wiring and appurtenances as herein specified, or as shown or implied on the drawings.

2. City Ordinances and State Laws

All electrical work shall be done in accordance with the National Board of Underwriters' Rules and Regulations, except where local or state laws conflict, in which case said laws shall govern.

3. Scope of Specifications

These specifications are intended to cover the installations of all electric light wiring and appurtenances from a point of supply to outlets for fixtures and apparatus.

4. Material

The Contractor shall submit with his proposal the manufacturer's name, type, catalog and identification numbers of all electrical devices and material to be used, also complete wiring diagrams in triplicate showing the size of all wires and grades of covering. Devices and material of equal grade may be substituted on approval of the Engineer, but no inferior material or obsolete devices will be accepted.

5. Conduits

Wiring shall be installed in approved rigid or flexible conduit, which shall be properly secured in place. Conduit shall be cut with a hack saw and ends thoroughly reamed. Conduits shall be free from sharp bends and of sufficient size to allow wires to be drawn without undue strain. During construction, ends of conduits shall be plugged at all outlets to keep the conduit dry and free from foreign matter.

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[36] Adopted, Vol. 27, 1926, pp. 1197, 1421.

Exposed conduit shall be run along beams, ceilings or walls, and not across open spaces unless properly supported by approved hangers, and shall be painted to match the finished color of background or completely masked by a molding, unless otherwise called for on drawings.

Conduit which is to be embedded in masonry must be placed during its construction. The cutting of chases will not be permitted.

Conduits shall not be installed in close proximity to heating pipes or hot air ducts.

6. Wires

Except for fixtures and pendant cords, the minimum size of wire shall be No. 14 A.W.G. All circuit wires shall be of such size as not to produce a drop in potential of more than 2 per cent and the entire system shall be calculated so as not to produce a drop in potential of more than 4 per cent.

Wire of No. 8 size A.W.G. and larger shall be stranded and may be single or double braid, according to local requirements.

Wires must have a distinct marking throughout their entire length, so that they can be easily identified. Coils must be plainly marked and tagged to show the name of manufacturer, date manufactured and the maximum voltage for which the insulation is designed.

7. Joints

Unless joints are made with an approved electrically efficient and rigid splicing device, they must be made mechanically and electrically secure without solder, then soldered and covered with insulation equal to that of the conductors.

8. Outlet Boxes

The Contractor shall provide and set metal outlet boxes of approved design and construction, suited to the requirements, at every light outlet and at every local switch outlet. Boxes must admit of being readily set or firmly joined to conduits. Conduit openings not in use shall be plugged or capped.

Boxes for all local switch outlets not at panel boards shall be of similar design to light outlet boxes. Gang boxes shall be used where switches are grouped.

Metal pull boxes shall be designed to allow of easy withdrawal and easy insertion of main and branch wires and shall be of approved type and design.

9. Service Switches and Cabinets

Service switches shall conform to local or Underwriters' Rules, and shall be essentially of the Safety First type, installed separately and easily accessible.

Circuit cabinets shall provide for one more circuit than indicated on drawings, and shall be provided with cylinder lock and a set of three keys.

10. Local Switches

The local switches shall be of not less than 10 amperes capacity, and shall be the style and type as indicated or directed. Where two or more switches come together, they are to be set in a gang box with one cover plate unless otherwise specified, finish of box shall match adjacent hardware.

11. Fuses

Main and feeder circuits shall be provided with fuses of the enclosed type, which shall indicate plainly the amperes and volts for which they are rated. Branch lighting circuits shall be provided with .... screw plug cutouts and where lights are to be controlled from cabinet, approved detachable push or toggle switches with insulated dead front covering, or equal, shall be installed.

12. Wiring Systems

Unless otherwise specified, wiring for lighting shall be a multiple wire system of 110 to 220 volts. Feeders and branch feeders shall consist of three wires, and the neutral wire shall in all cases have the same current carrying capacity as the outside wires. Branch circuits shall be two-wire. No branch circuit shall carry more than 660 watts except where especially approved.

13. Outside Work

Exact locations to which the service company will bring service wires shall be ascertained by the Contractor, and he shall carry his work to the source of supply as a part of this contract.

14. Outside Wiring

Wire shall be brought in overhead only when so specified.

The Contractor shall furnish necessary meter loops of suitable approved fused safety service switches as hereinbefore specified, and extend the service wires through the exterior walls of building for ready connection with service company's supply wires.

Wire supported on the exterior walls of buildings shall be carried on approved racks or brackets not more than 10 feet apart, and parallel wires shall be spaced not less than 6 inches apart.

Any wiring outside the building, either underground or overhead, that is to be installed by the Contractor shall conform to the requirements of the American Railway Association for line construction.

15. General Conditions and Guarantee

The Contractor must guarantee all workmanship and materials to be first-class and shall, at his own expense, replace or repair promptly upon receipt of written notice, any defects in material or workmanship which may develop within one year of acceptance of the work by the railroad company.

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

Section 21

[37]BRICK PAVEMENTS AND FLOORS

(In preparation.)

Section 22

[38]CONCRETE PAVEMENTS AND FOUNDATIONS

1. General

The Contractor shall furnish all labor, material, tools and equipment necessary to entirely complete the work as herein specified and shown on the drawings.

2. Description

The pavement shall consist of a subgrade and one course of concrete of the thickness shown on drawings, together with a curb and gutter as shown or indicated.

3. Grading and Subgrade

The grading shall be completed to the proper subgrade elevation to permit the specified thickness of pavement to be laid to bring the finished surface of the pavement to the established lines and grades.

The bottom of the excavation or top of the fill, when completed, shall be known as the subgrade.

The subgrade shall be constructed to have, as nearly as practicable, a uniform density throughout its entire width. It is not intended that the rolling shall be continued beyond this point, as the purpose of rolling is not to produce a subgrade that cannot be further compacted but to produce a uniformly compacted subgrade.

All soft, spongy or yielding spots and all vegetable or perishable matter shall be entirely removed from the subgrade and the space filled with suitable material.

Where a fill is required to bring the subgrade to the required elevation, it shall be made in layers not to exceed six (6) inches in thickness and each layer shall be thoroughly rolled or tamped.

Compression of the subgrade material shall be accomplished with a self-propelled roller weighing not less than five (5) tons. Hand tamping, where directed by the Engineer, shall be done with a tamp weighing not less than fifty (50) lb. and whose face does not exceed one hundred (100) square inches in area.

All hauling shall be distributed over the width of the subgrade so far as practicable, so as to leave it in a uniformly compacted condition.

Wherever the subgrade extends beyond the lateral limits of an old roadway or wherever an old gravel, macadam, or other hard compacted crust comes within 6 in. of the elevation of the finished subgrade, such old roadway or crust shall be plowed, loosened or scarified to a depth of at least 6 inches and the loosened material redistributed across the full width of the subgrade, adding suitable material, when necessary. Neither fine nor coarse aggregate shall be deposited upon the subgrade before it has been shaped and brought to the true finish.

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[37] In preparation.

[38] Adopted, Vol. 29, 1928, p. 939; Vol. 30, 1929, p. 1470.

All depressions and ruts developing under traffic on the subgrade or in connection with rolling, shall be filled with suitable material.

Shoulders, berms or ridges of earth or other material that will interfere with the immediate discharge of water from the subgrade to the side ditches shall not be left on the subgrade.

Special treatment may be required for certain subgrades such as sand, gumbo, adobe and other materials, which cannot be satisfactorily prepared by the methods specified in the foregoing paragraphs.

After being prepared in the manner above specified, the subgrade shall be so maintained until the concrete pavement has been placed thereon.

Surplus excavated material shall be disposed of by the contractor. The Contractor shall remove all obstructions such as trees, stones, blocks, etc.

4. Curbing

Concrete curbing shall be built according to details shown on drawings.

5. Concrete Materials and Workmanship

All cement and concrete materials and workmanship shall comply with the specifications for concrete as given in Section No. 4 of these specifications. Not more than five (5) gallons of water shall be used to each sack of cement.

6. Joint Filler

Joint filler shall consist of prepared strips of fiber matrix and bitumen, or a uniform mixture of fiber and bitumen, or a combination of both, containing not more than 25% by weight of inert material, having thickness of . . . . inches and width equal to . . . . inches greater than the thickness of the pavement at any point. The bitumen used in manufacture of the joint filler may be either tar or asphalt of a grade that will not become soft enough to flow in hot weather nor brittle in cold weather.

7. Forms

Forms shall comply with the specifications for concrete as given in Section No. 4 of these specifications. Wooden forms shall be straight, dressed on at least one side, not less than 2 inches (nominal) in thickness and equal in width to the depth of the concrete which is to be placed against them. Wooden forms shall be held in place by stakes driven into the ground along the outside edge at intervals of not more than 6 feet, two stakes being placed at each joint. The forms shall be firmly nailed to the side stakes and braced to resist the pressure of the concrete or the impact of tamping.

Metal forms shall be of shaped sections. They shall be straight, have a depth equal to the depth of the concrete to be placed against them and sufficient strength to resist without springing the working strains to which they are subjected.

8. Joints

The joints to be formed shall be transverse or longitudinal. They shall be tested with a 10-ft. straightedge during and after finishing and any irregularities in the surface shall be immediately corrected.

In pavements with integral curb and gutter, joints shall be continuous in a straight line through pavement and curb.

Manhole and catchbasin covers and all other fixed objects in the pavement shall be separated from the concrete by joint filler.

All joints shall extend through the entire thickness of the pavement; shall be perpendicular to the surface of the pavement, and be edged to a radius of ¼ inch.

9. Expansion Joints

Transverse expansion joints shall be placed across the pavement perpendicular to the center line. They shall be ⅜ inch wide and spaced 35 ft. apart between intersections. A bulkhead cut to the exact cross-section of the pavement shall be securely staked in place at right angles to the center line and surface of the pavement. The premolded joint filler shall be cut to conform to the cross-section of the pavement and in lengths equal to the width of the pavement, except that strips equal in length to half the width of the pavement may be used when laced or clipped together at the center in a workmanlike and effective manner. The joint filler shall be placed against the bulkhead and held in position by pins on which there is an outstanding lug. Before the bulkhead is removed concrete shall be deposited on both sides of it. After the concrete has been brought to the proper crown the bulkhead shall be removed by lifting it slowly from one end and replacing it with concrete as it is lifted. so that the joint filler will be left in the correct position.

Before the pavement is opened to traffic the joint filler shall be trimmed off to a uniform height of ¼ inch above the surface of the pavement.

Expansion joints in intersections shall be located as shown on the drawings or as directed by the Engineer.

When expansion joints are made at the end of the day's work they shall be formed by finishing the concrete to the bulkhead, placed as before specified. When work is resumed the joint filler shall be placed against the hardened concrete and held in position by pins until fresh concrete is placed against it.

Longitudinal expansion joints shall be formed by placing the filler against the form, bulkhead, curb, or adjacent structure and placing the concrete against it. The filler shall extend the full depth of the pavement, and be flush with the pavement surface.

10. Longitudinal Dividing Joint

When the whole width of the pavement is placed in one operation, and longitudinal joints are used they shall be formed by embedding in the pavement a strip of galvanized or painted 18 gage, corrugated sheet metal 1 inch less in depth than the depth of the pavement at the joint. The metal shall be accurately staked to line and grade by means of pins driven vertically through holes provided for that purpose at not more than 4 feet intervals. The pins shall be of mild steel ¼ inch in diameter and at least 15 inches long, and shall be left in place. The metal strips may be of any length. Punched or cut holes shall be provided in the strips at 5 foot intervals to receive ½ inch round tie bars embedded 2 feet on each side of joint. The metal shall be carefully placed in the proper location and be vertical when the concrete is deposited about it.

When the pavement is built in successive longitudinal strips, longitudinal joints shall be formed by painting the edge of sections first built with a bituminous paint and depositing the concrete in adjacent section against the painted edge.

11. Placing Reinforcement

Steel fabric reinforcement when called for on the drawings shall be placed 2 inches below and parallel to the finished surface of the pavement unless otherwise indicated. Fabric shall extend to within 2 inches of sides and ends of slabs. All laps of fabric sections shall be not less than three-fourths of the spacing of members in the direction lapped.

Steel bar reinforcement when called for on the drawings shall be placed 3 inches below the finished surface of the pavement unless otherwise indicated. Transverse bars shall extend to within 2 inches of the margins of the pavement. Bar reinforcement shall be placed and securely supported in correct position before any concrete is laid. All intersections of longitudinal and transverse bars shall be securely wired or clipped together to resist displacement during concreting operations.

12. Placing Concrete

Concrete shall be placed only on a moist subgrade, but there shall be no pools of standing water. If the subgrade is dry, it shall be sprinkled with as much water as it will absorb readily.

The mixed concrete shall be deposited rapidly on the subgrade to the required depth and for the entire width between longitudinal joints in successive batches and in a continuous operation without the use of intermediate forms or bulkheads between joints. While being placed, the concrete shall be vigorously sliced and spaded, with suitable tools, to eliminate voids or honeycomb pockets. The concrete shall be especially well spaded and tamped against forms, bulkheads, curbs and gutters.

When the concrete is placed in two layers to permit the use of steel fabric reinforcement, the first layer shall be roughly struck off with a template or lute at the correct elevation to permit placing the reinforcement in the specified position. The concrete above the reinforcement shall be placed within 15 minutes after the first layer has been placed.

13. Finishing

(a) STRIKING OFF.—Between intersections the concrete shall be brought to the specified contour by means of a screed or template, fitted with handles and weighing not less than 15 lb. per lin. ft. This template may be of steel, or of wood shod with steel. It shall be shaped to the contour of the pavement and have sufficient strength to retain its shape under all working conditions.

The template shall rest on the side forms, curbs or gutters and shall be drawn forward with a sawing motion. At transverse joints the template shall be drawn not closer than 3 feet toward the joint and shall then be lifted and set down at the joint and drawn backward away therefrom. Surplus concrete shall then be taken up with shovels.

(b) TAMPING.—After the concrete has been struck off, the template shall be used as a tamp. In this operation one end of the template shall rest on the side support, while the other is lifted and dropped, advancing at such a rate that the whole pavement is struck at least once. The opposite end shall then be lifted and dropped and advanced in the same manner. In no case shall either end be advanced more than 1 foot ahead of the other.

(c) LUTING.—Instead of screeding with a template as specified above in (a), the correct pavement contour may be secured by the use of a lute. In that case steel grade stakes provided with lugs shall be driven into the subgrade with the top of the lugs accurately set at the elevation for the finished pavement. These stakes shall be set at intervals of 10 ft. along the subgrade and in a straight line perpendicular to the center line of the pavement, one at the center line and one at each quarter point and at as many additional points as the Engineer may direct. The concrete shall then be spread to the elevation indicated by the stakes.

(d) IMPERFECTIONS —Immediately after the screeding or luting has been completed, the surface shall be inspected for high or low spots and any needed corrections made by adding or removing concrete. Rough spots shall be gone over with a long handled float and worked to proper contour and grade. The entire surface shall then be floated longitudinally, with a float board not less than 16 ft. long and 8 in. wide. This float board shall have convenient plow-handles at each end. It shall be operated by two men, one at each end, each man standing on a bridge spanning the pavement. The lower surface of the float board shall be placed upon the surface of the concrete with the long dimension parallel to the center line of the pavement. The float shall then be drawn back and forth in slow strokes about 2 ft. long, and advancing slowly from one side of the pavement to the other. The purpose of this operation is to produce a uniform even surface on the concrete, free from transverse waves. The two bridges on which the workmen stand should be placed about 18 feet apart when the length of the float is 16 feet. When the entire width of the pavement has been floated in this manner from one position of the bridges, they shall be moved ahead about 12 feet so that the next section to be floated shall overlap the one previously floated from 3 to 4 feet.

Cement mortar gathered from the surface of the concrete already placed shall not be used in filling boot tracks or stony areas, but such imperfections shall be dug out and refilled with concrete to the depth of the reinforcing and worked smooth. No person shall then be allowed to walk over the area so completed.

(e) BELTING.—The concrete shall be finished by using a belt of wood, canvas or rubber, not less than six nor more than 12 inches wide, and at least 2 feet longer than the width of the pavement. The belt shall be applied with a combined crosswise and longitudinal motion. For the first application vigorous strokes at least 12 inches long shall be used, and the longitudinal movement along the pavement shall be very slight. The second application of the belt shall be immediately after the water sheen disappears, and the stroke of the belt shall be not more than 4 inches and the longitudinal movement shall be greater than for the first belting.

The Contractor shall provide a suitable split float or split roller having a slot to fit over expansion joints. This device shall be so arranged as to float the surface for a width of at least 3 feet on each side of the joint simultaneously. This device shall be used in such manner as to produce a true surface across the joint. Edges of the pavement, at joints and side shall be tooled for a width of 2 inches, the corners rounded to a radius of ¼ inch.

14. Curing and Protection

The Contractor shall provide a sufficient amount of burlap or canvas to cover all the pavement laid in any one day's maximum run. Burlap or canvas cover shall be made up in sheets 12 ft. wide, and 4 ft. longer than the width of the pavement. Burlap or canvas cover shall be placed on the concrete immediately after the final belting, and shall then be sprayed with water in such a manner that the surface of the pavement will not be damaged. Burlap or canvas cover shall be kept continuously moist by spraying until the concrete has taken final set.

As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than 2 in. of earth or 6 inches of hay or straw. This cover shall be kept continuously wet by spraying for 10 days after the concrete is laid.

The ponding or the spraying method of curing may be used when and as approved by the Engineer. After 14 days, the earth or other cover may be removed. After 30 days the Contractor may use a mormon or a fresno scraper to remove the cover, except that scrapers shall not be used within 1 ft. of expansion joints. The cover within 1 ft. of expansion joints must be removed by hand. Road machines or blade graders of the 2 or 4 wheel type shall not be used for removing the cover.

After the cover has been removed or ponds emptied and dikes removed, the entire surface of the pavement shall be swept clean and free from dirt and débris. Horse or motor drawn sweepers shall not be operated on the pavement till 20 days have elapsed after the concrete is placed.

15. Prohibition of Traffic

The Contractor shall provide and maintain substantial barricades across the pavement, with suitable warning signs by day and by night, to prevent traffic of any kind upon the pavement before it is 20 days old.

16. Adjusting Existing Structures

Manhole and catchbasin covers, valve boxes and similar existing structures within the area to be paved shall be adjusted by the Contractor to come flush with the surface of the pavement.

17. Guarantee

It is hereby understood and agreed that the Contractor shall guarantee the material furnished and used and the workmanship employed in the construction of said improvements to be of such quality and character as to insure the same to be free from all defects and to remain in continuous good order and condition satisfactory to the Engineer of the Railroad Company as above set forth for a period of two (2) years. The guarantee shall include all repairs to be made or, if necessary, the entire reconstruction of the work as the Engineer of the Railroad Company may direct without additional charge or cost to the Railroad Company.

In case the paving, or any part thereof, is on public property where city ordinance or other ruling requires a maintenance bond, the Contractor shall furnish within ten (10) days after the contract is let, a good and satisfactory bond to the amount as stated in the general contract to maintain that portion of the work on said public property as covered by this contract at the finished line and grade for a period of years as required by said ordinance or ruling.

18. General Conditions

All materials entering into the work and all methods used by the Contractor shal be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of these specifications shall be considered to apply with equal force to this specification.

Section 23-A

[39]CREOSOTED WOOD BLOCK PAVEMENTS

1. General

The Contractor shall furnish all labor, materials, tools and equipment except as otherwise noted, necessary to complete entirely the creosoted wood block pavement as hereinafter specified, and as shown or implied on the drawings.

2. Description

The pavement shall consist of a subgrade and concrete foundation and a wearing course of creosoted wood blocks laid over either a bituminous paint coat, a mortar bed or a bituminous mastic cushion, applied to such foundation.

3. Grading, Subgrade and Foundation

The grading, subgrade and foundation shall be constructed in accordance with the current specification of the A.R.E.A. for Concrete Pavements, except, however, joints shall be omitted and the concrete finished to a smooth even surface exactly the depth below the finished pavement, corresponding to the combined depth of the wood block and the thickness of the paint coat, mortar bed, or mastic cushion to be used.

4. Curb and Gutter

The curb or the curb and gutter shall be built in the location and to the elevation, sizes and cross-section shown on drawings.

All cement and concrete materials and workmanship shall comply with the specifications for Concrete as given in Section No. 4 of these specifications.

5. Kind of Blocks

The wood from which the blocks are to be manufactured shall be Douglas fir, Norway pine, southern yellow pine, tamarack, western larch or other suitable wood approved by the Engineer. Blocks from only one kind of wood shall be used in any one contract, and they shall first be treated with a preservative as hereinafter specified.

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[39] Adopted, Vol. 29, 1928, p. 945; Vol. 30, 1929, p. 1470.

6. Quality of Blocks

The blocks must be sound and well manufactured, square butted, square edged, free from unsound or loose knots, holes, shakes, checks or other defects that will impair their usefulness for pavement.

In Douglas fir or southern yellow pine, the number of annual rings in the 1-inch which begins 2 inches from the pith of the block shall be not less than six, measured radially; provided, however, that blocks containing between five and six rings in this inch shall be accepted if they contain 33⅓ per cent or more of summerwood. In case the block does not contain the pith, the 1 inch to be used shall begin 1 inch away from the ring which is nearest to the heart of the block.

7. Size of Blocks

The blocks may vary in length from 5 to 10 inches, the maximum length not to exceed two and one-half times the depth; they shall be 2½ to 4 inches in depth (parallel to fiber), according to condition of traffic; and they may be 2¾ to 4¼ inches in width, but in any one job all of them shall be of uniform width and depth. A variation of 1/16 inch will be allowed in the depth and ⅛ inch in the width of the blocks from that specified. In all cases the width shall be greater than the depth by at least ¼ inch.

8. Preservative Treatment

The preservative shall be either Coal Tar Paving Oil of the American Wood Preservers' Association or Grade 1 Creosote Oil of the A.R.E.A. as the Engineer directs. The method of treatment used, the amount of preservative to be contained in the blocks after treatment and the method of its determination, and the superficial condition of the blocks after treatment, shall be in accordance with the current "Standard Specification for Creosoted Wood Block Street Paving" adopted by the American Wood Preservers' Association.

9. Inspection of Blocks

All material herein specified and processes used in the manufacture of the blocks therefrom shall be subject to inspection, acceptance, or rejection at the plant of the manufacturer, which shall be equipped with all the necessary gages, appliances and facilities to enable the inspector to satisfy himself that the requirements of the specifications are fulfilled. The Engineer shall have the further right to inspect the blocks after delivery upon the street for the purpose of rejecting any blocks that do not meet these specifications, except that the plant inspection shall be final with respect to the kind of wood, rings per inch, preservative and treatment.

10. Method of Laying Blocks

The Contractor shall furnish and lay the wood blocks under the direct supervision of the manufacturer and shall arrange for such supervision. Blocks shall be laid either by the Bituminous Paint Coat Method or by the Mortar Bed Method or by the Bituminous Mastic Cushion Method of the American Wood Preservers' Association as the Engineer directs and as set forth hereinbelow.

(a) Bituminous Paint Coat Method.—Upon the concrete foundation, which shall first be thoroughly cleaned and dried, shall be spread a thin, hot, uniform coating of coal tar pitch, special pitch filler, or asphalt, conforming to the current standard specifications for such materials and methods of their test adopted by the American Wood Preservers' Association. The bitumen shall be heated to a temperature of not less than 250 deg. Fahr., and not more than 300 deg. Fahr., and mopped or flushed over the concrete, while hot, to a uniform thickness of not to exceed ⅛ inch.

Upon the hardened bituminous paint coat, thus prepared, the blocks, which shall have been thoroughly dried out after treatment, shall be carefully set with the fiber of the wood vertical, in straight parallel courses with their length at right angles to line of traffic, leaving a space next to the curb 1 inch in width for an expansion joint.

The blocks shall be driven together every fourth course, to keep the rows straight and to eliminate subsequent slippage. No joint shall be more than $\frac{3}{16}$ inch in width. Nothing but whole blocks shall be used, except in starting or ending a course, and all joints shall be broken by a lap of at least 2 inches. The courses shall extend at right angles to the curb. After the blocks have been laid they shall be rolled parallel and diagonally to the curb by a tandem roller weighing between 2½ and 5 tons until the surface becomes smooth and is brought truly to the grade and contour of the finished pavement.

(b) Mortar Bed Method.—Upon the concrete foundation, which shall first be cleaned and thoroughly wetted and which shall be finished to within ½ inch of the given grade, shall be spread a layer of thoroughly mixed dry mortar, not exceeding ¾ inch in thickness and consisting of one part of Portland cement, of the character provided for in the foundation, and three parts of sand. Only sufficient water shall be added to this mixture to insure a proper setting of the cement, the intention being to produce a granular mixture which may be raked to the desired grade. The mortar shall be spread in place on the foundation immediately in advance of the laying of the blocks. The mortar bed shall be raked to the approximate grade in uniform density and struck by template to a surface parallel to the grade and contour of the finished pavement.

Upon the mortar bed thus prepared, after lightly sprinkling it with water, the blocks shall be carefully set with the fiber of the wood vertical, in straight, parallel courses with their length at right angles to the line of traffic, leaving a space next to the curb 1 inch in width for an expansion joint. The blocks shall be laid in the pavement as soon as possible after being treated. If they cannot be laid immediately, provision shall be made to prevent them from drying out by stacking in close piles and covering and sprinkling them thoroughly at intervals.

The blocks shall be laid by setting them hand-tight on the mortar bed. No joint shall be more than $\frac{3}{16}$ inch in width. They may be driven together every ten courses to keep the rows straight. Nothing but whole blocks shall be used, except in starting or ending a course, and all joints shall be broken by a lap of at least 2 inches. The courses shall extend at right angles to the curb.

After the blocks have been laid and before the mortar has set, they shall be rolled parallel and diagonally to the curb by a tandem roller weighing between 4 and 7 tons until the surface becomes smooth and is brought truly to the grade and contour of the finished pavement. All mortar that has set before the blocks are in place and rolled shall be discarded and replaced by fresh mortar.

(c) BITUMINOUS MASTIC CUSHION METHOD.—Upon the concrete foundation which shall first be thoroughly cleaned and dried and which shall be finished to within ½ inch of the given grade, shall be spread a layer of mastic, not exceeding ¾ inch in thickness, and consisting of approximately 10 per cent suitable bituminous material, either coal tar pitch or asphaltic oil conforming to the current standard specifications for such materials and methods of their test adopted by the American Wood Preservers' Association and 90 per cent clean, dry, screened sand. The mastic shall be thoroughly mixed and spread to the approximate grade in a uniform density and struck by template to a surface parallel to the grade and contour of the finished pavement. This cushion shall be spread a day in advance of the placing of the blocks to allow the mastic to cure.

Upon the cushion thus prepared, the blocks shall be carefully set with the fiber of the wood vertical, in straight, parallel courses with their length at right angles to the line of traffic, leaving a space next to the curb 1 inch in width for an expansion joint.

The blocks shall be laid by setting them hand-tight on the cushion. No joint shall be more than 3/16 inch in width. They may be driven together every ten courses to keep the rows straight. Nothing but whole blocks shall be used, except in starting or ending a course, and all joints shall be broken by a lap of at least 2 inches. The courses shall extend at right angles to the curb.

After the blocks have been laid on the cushion they shall be rolled parallel and diagonally to the curb by a tandem roller weighing between 4 and 7 tons until the surface becomes smooth and is brought truly to the grade and contour of the finished pavement.

11. Expansion Joints and Filler

Against the curb, a bituminous expansion joint one inch in width shall be formed by laying strips of that width along the curb line. After the rolling and surfacing has been completed and after removal of the strips, these spaces and the joints between the blocks shall be filled with a bituminous filler, of either coal tar pitch, special pitch filler or asphalt conforming to the current standard specifications for such materials and methods of their test adopted by the American Wood Preservers' Association.

The filler shall preferably be applied only when the temperature of the air is above 45 deg. Fahr. It shall be heated to the highest possible temperature without burning or injuring its consistency and at that temperature shall be applied by flushing over the surface of the blocks, working it into the spaces and joints by means of a hard rubber-edged squeegee. Care must be exercised to fill the joints uniformly and not leave any surplus filler on the surface. The surface of the pavement shall then be completely covered to a depth of about ½ inch with coarse, clean, sharp sand or stone screenings which shall be permitted to remain under traffic for several weeks.

The kettles in which the filler is heated shall be equipped with tested thermometers.

12. Grades of Three Per Cent or Over

When the blocks are laid on streets having grades of 3 per cent or over, it is desirable that the courses shall be spaced with open joints. This spacing may be secured by laying creosoted wood lath about $\frac{5}{16}$ inch thick between each course, or by other approved methods. The space between the blocks shall then be filled with a mastic filler, consisting of equal parts of stone screenings and bitumen, as specified above. The joints shall be filled about ⅔ full of the bituminous mastic filler above specified, care being taken to leave as little as possible on the surface of the pavement. Stone screenings shall then be spread over the surface of the pavement and permitted to work into the top of the joints under traffic. It is essential to drive the blocks together every four courses to prevent tipping and slipping of the individual blocks.

13. Adjusting Existing Structures

Manholes and catchbasin covers, valve boxes, and similar existing structures within the area to be paved shall be adjusted by the Contractor to come flush with the pavement surface.

14. Guarantee

It is hereby understood and agreed that the Contractor shall guarantee the material furnished and used and the workmanship employed in the construction of said improvements to be of such quality and character as to insure the same to be free from all defects and to remain in continuous good order and condition satisfactory to the Engineer of the Railroad Company as above set forth for a period of two (2) years. The guarantee shall include all repairs to be made or, if necessary, the entire reconstruction of the work as the Engineer of the Railroad Company may direct without additional charge or cost to the Railroad Company.

In case the paving or any part thereof is on public property where city ordinance or other ruling requires a maintenance bond, the Contractor shall furnish within ten (10) days after the contract is let, a good and satisfactory bond to the amount as stated in the general contract to maintain that portion of the work on said public property as covered by this contract at the finished line and grade for a period of years as required by ordinance or ruling.

15. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this specification.

Section 23-B

[40]WOOD BLOCK FLOORS

1. General

The Contractor shall furnish all labor, materials, tools and equipment, except as otherwise noted, necessary to complete entirely the wood block floors as hereinafter specified, and as shown or implied on the drawings.

2. Description

The floor shall consist of a subgrade, a concrete foundation and a wearing course of wood blocks laid over either a bituminous paint coat, a mortar bed, or a bituminous mastic cushion, applied to such foundation.

3. Subgrade and Foundation

The subgrade, if one be needed, and foundation shall be designed of sufficient strength to carry the loading to be encountered and shall be constructed in accordance with the current specification of the A.R.E.A. for Concrete for railway buildings as given in Section 4 of these specifications, except that the concrete shall be finished to a smooth even surface, with no projections of any kind, parallel to the contour of and exactly the depth below the finished floor level, corresponding to the combined depth of the block and the thickness of the paint coat, mortar bed, or mastic cushion to be used.

4. Kind of Blocks

The wood from which the blocks are to be manufactured shall be Douglas fir, Norway pine, red cypress, redwood, southern yellow pine, tamarack, western larch, or other suitable wood approved by the Engineer. Blocks from only one kind of wood shall be used in any one contract, and they shall first be treated with a preservative as hereinafter specified except blocks of red cypress and redwood which may be used untreated and shall be well seasoned.

5. Quality of Blocks

The blocks must be sound and well manufactured, square butted, square edged, free from unsound or loose knots, holes, shakes, checks, or other defects that will impair their usefulness for floors.

In Douglas fir or southern yellow pine, the number of annual rings in the 1 inch which begins 2 inches from the pith of the block, shall be not less than six, measured radially; provided, however, that blocks containing between five and six rings in this inch shall be accepted if they contain 33⅓ per cent or more of summerwood. In case the block does not contain the pith, the 1 inch to be used shall begin 1 inch away from the ring which is nearest to the heart of the block.

6. Size of Blocks

The blocks may vary in length from 5 to 8 inches, the maximum length not to exceed three times the depth; they shall be 2½ to 4 inches in depth (parallel to fiber); and they may be 2¾ to 4¼ inches in width, but on any one floor all of them shall be of uniform width and depth. A variation of $\frac{1}{16}$ inch will be allowed in the depth and ⅛ inch in the width of the blocks from that specified. In all cases the width shall be greater than the depth by at least ¼ inch.

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[40] Adopted, Vol. 29, 1928, p. 950; Vol. 30, 1929, p. 1470.

7. Preservative Treatment

The preservative shall be either coal tar paving oil of the American Wood Preservers' Association or Grade 1 Creosote Oil of the A.R.E.A. as the Engineer directs. The treatment to be used, the amount of preservative to be contained in the blocks after treatment and method of its determination, and the superficial condition of the blocks after treatment, shall be in accordance with the current "Standard Specification for Interior Creosoted Wood Block Flooring" adopted by the American Wood Preservers' Association in case the blocks are to be used under dry floor conditions, and in accordance with the current "Standard Specification for Creosoted Wood Block Street Paving" adopted by the same association in case the blocks are to be used under wet floor conditions.

8. Inspection of Blocks

All material herein specified and processes used in the manufacture of blocks therefrom shall be subject to inspection, acceptance, or rejection at the plant of the manufacturer, which shall be equipped with all necessary gages, appliances, and facilities to enable the inspector to satisfy himself that the requirements of the specification are fulfilled. The Engineer shall have the further right to inspect the blocks upon delivery for the purpose of rejecting any blocks that do not meet these specifications, except that the plant inspection shall be final with respect to the kind of wood, rings per inch, oil and treatment.

9. Method of Laying Blocks

The Contractor shall furnish and lay the wood blocks under the direct supervision of the manufacturer and shall arrange for such supervision. Blocks shall be laid either by the Bituminous Paint Coat Method or by the Mortar Bed Method or by the Bituminous Mastic Cushion Method of the American Wood Preservers' Association as the Engineer directs and as set forth hereinbelow.

(a) BITUMINOUS PAINT COAT METHOD.—Upon the concrete foundation, which shall first be thoroughly cleaned and dried, shall be spread a thin, hot, uniform coating of coal tar pitch or asphalt, conforming to the current standard specifications for such materials and methods of their test adopted by the American Wood Preservers' Association, except that the melting point shall be not less than 130 deg. Fahr. nor more than 150 deg. Fahr. It shall be heated to a temperature of not less than 250 deg. Fahr. and not more than 300 deg. Fahr. and mopped or flushed over the concrete, while hot to a uniform thickness of not to exceed ⅛ inch.

Upon the hardened bituminous paint coat thus prepared, the blocks, which shall have been thoroughly dried out and under dry floor conditions preferably have been seasoned for a period of 30 to 60 days after treatment, or under wet floor conditions shall have been well sprinkled with water about two days before being laid, shall be carefully set with the fiber of the wood vertical, in straight parallel courses with their length at right angles to the line of traffic, leaving a space next to all walls, columns, and other obstructions, 1 inch in width for an expansion joint. Nothing but whole blocks shall be used, except in starting or ending a course, and all joints shall be broken by a lap of at least one inch.

Under dry floor conditions, the blocks shall be driven as tightly together as possible by ramming both in the direction of the courses and at right angles to them before the floor is rolled or surfaced. Under wet floor conditions, the blocks must not be driven up tightly together when wet or humid conditions are encountered.

After the blocks have been laid they shall be thoroughly tamped or rolled to a smooth level surface.

(b) Mortar Bed Method.—Upon the concrete foundation, which shall first be cleaned and thoroughly wetted and which shall be finished to within ½ inch of the given floor level, shall be spread a layer of thoroughly mixed dry mortar, not exceeding ½ inch in thickness and consisting of one part of Portland cement, of the character provided for in the foundation, and three parts of sand. Only sufficient water shall be added to this mixture to insure a proper setting of the cement, the intention being to produce a granular mixture which may be raked to the desired grade. This mortar shall be spread in place on the foundation immediately in advance of the laying of the blocks. The mortar bed shall be raked to the approximate grade in a uniform density and struck by template to a surface parallel to the grade and contour of the finished floor.

Upon the mortar bed thus prepared, after lightly sprinkling it with water, the blocks, which shall have been thoroughly dried out and under dry floor conditions preferably have been seasoned for a period of 30 to 60 days after treatment, or under wet floor conditions shall have been well sprinkled with water about two days before being laid, shall be carefully set with the fiber of the wood vertical, in straight parallel courses with their length at right angles to the line of traffic, leaving a space next to all walls, columns, and other obstructions, 1 inch in width for an expansion joint. Nothing but whole blocks shall be used, except in starting or ending a course, and all joints shall be broken by a lap of at least one inch.

Under dry floor conditions, the blocks shall be driven as tightly together as possible by ramming both in the direction of the courses and at right angles to them before the floor is rolled or surfaced. Under wet floor conditions the blocks must not be driven up tightly together when wet or humid conditions are encountered.

After the blocks have been laid and before the mortar has set, they shall be thoroughly tamped or rolled to a smooth level surface. All mortar that has set before the blocks are in place and rolled shall be discarded and replaced by fresh mortar.

(c) Bituminous Mastic Cushion Method.—Upon the concrete foundation, which shall first be thoroughly cleaned and dried and which shall be finished to within ½ inch of the given floor level, shall be spread a layer mastic, not exceeding ¾ inch in thickness consisting of approximately 10 per cent suitable bituminous material, either coal tar pitch or asphaltic oil, conforming to the current standard specifications for such materials and methods of their test adopted by the American Wood Preservers' Association, and 90 per cent clean, dry, screened sand. The mastic shall be thoroughly mixed and spread to the approximate grade in a uniform density and struck by template to a surface parallel to the grade and contour of the finished floor. This cushion shall be spread a day ahead of the placing of the blocks to allow the mastic to cure.

Upon the cushion thus prepared, the blocks, which shall have been thoroughly dried out and under dry floor conditions preferably have been seasoned for a period of 30 to 60 days after treatment, or under wet floor conditions shall have been well sprinkled with water about two days before being laid, shall be carefully set with the fiber of the wood vertical, in straight parallel courses with their length at right angles to the line of traffic, leaving a space next to all walls, columns, and other obstructions, 1 inch in width for an expansion joint. Nothing but whole blocks shall be used, except in starting or ending a course, and all joints shall be broken by a lap of at least one inch.

Under dry floor conditions, the blocks shall be driven as tightly together as possible by ramming both in the direction of the courses and at right angles to them before the floor is rolled or surfaced. Under wet floor conditions the blocks must not be driven up tightly together when wet or humid conditions are encountered.

After the blocks have been laid they shall be thoroughly tamped or rolled to a smooth level surface.

10. Expansion Joints and Filler

Against the walls on all sides of the floor, as well as around all columns and other obstructions, a bituminous expansion joint 1 inch in width shall be formed by laying strips of that width against and round them. After tamping or rolling has been completed and after removal of the strips, these spaces and the joints between the blocks shall be filled to within an inch of the top with a bituminous filler, of either coal tar pitch or asphalt conforming to the current standard specifications for such materials and methods of their test adopted by the American Wood Preservers' Association.

The filler shall be heated to the highest possible temperature without burning or injuring its consistency, and at that temperature shall be applied by flushing over the surface of the floor, working it into the spaces and joints by means of a rubber edged squeegee. Care must be exercised to fill the joints uniformly and not to leave any surplus filler on the surface. The surface of the floor shall then be covered with sharp, fine sand, which shall be permitted to remain under traffic for a week or ten days. The light film of bituminous material on the surface of the blocks will wear off readily under traffic.

The kettles in which the filler is heated shall be equipped with tested thermometers.

11. Guarantee

It is hereby understood and agreed that the Contractor shall guarantee the material furnished and used and the workmanship employed in the construction of said interior flooring to be of such quality and character as to insure the same to be free from all defects and to remain in continuous good order and condition satisfactory to the Engineer of the Railroad Company as above set forth for a period of two (2) years. The guarantee shall include all repairs to be made, or, if necessary, the entire reconstruction of the work as the Engineer of the Railroad Company may direct without additional charge or cost to the Railroad Company.

12. General Conditions

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this specification.

Section 24

[41]ASPHALT PAVEMENTS AND FLOORS

(In preparation.)

Section 25-A

[42]ASPHALT BLOCK PAVEMENTS

1. General

The Contractor shall furnish all labor, material, tools and equipment except as otherwise noted, necessary to entirely complete the asphalt block paving as hereinafter specified, and as shown or implied on the drawings.

2. Description

The pavement shall consist of a subgrade, a concrete foundation and asphalt blocks laid thereon in a mortar bed.

3. Grading, Subgrade and Foundations

Grading, subgrade and foundation shall be constructed in accordance with the current specifications of the A.R.E.A. for Concrete Pavement, except that joints shall be omitted, and the concrete finished to a smooth even surface, exactly the depth below the finished pavement corresponding to the combined depth of the block and the thickness of the mortar bed used.

4. Curb and Gutter

The curb and gutter shall be built in the location and to the elevation, sizes and cross-section shown on drawings.

All cement and concrete materials and workmanship shall comply with the specifications for Concrete as given in Section 4 of these specifications.

5. Blocks

Asphalt blocks shall be of .... make compressed to at least 4000 lb. per square inch at 225 deg. Fahr. Blocks shall be 5 inches in width, 12 inches in length unless the depth required is less than 2 inches, in which case they shall be 4 inches in width by 8 inches in length. The depth shall be shown on the drawings. A variation either way from these dimensions of ¼ inch in length or ⅛ inch in width or depth will be sufficient cause for rejection of any block.

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[41] In preparation.

[42] Adopted, Vol. 29, 1928, p. 954; Vol. 30, 1929, p. 1470.

6. Mortar Bed

There shall be placed upon the surface of the foundation, which is to be cleaned and wetted, a bed of cement mortar ½ inch in thickness. This mortar bed shall be composed of Portland cement and clean, sharp sand, which shall be free from pebbles over ¼ inch in diameter. The mortar shall be made in proportions of one part cement to four parts of sand. The ingredients shall be mixed with good clean water to such consistency that it can easily be spread upon the surface and struck with template to a smooth and even face. It must not, however, be so thin as to allow the blocks to sink into the mortar when placed thereon. This mortar shall be struck to a true surface exactly parallel to the top of the finished pavement and the required depth of the block below it, in the following manner.

On the surface of the foundation shall be set strips of wood 4 inches wide by ¼ inch thick, and of a convenient length or strips of metal 4 inches wide by ⅛ inch or $\frac{3}{16}$ inch thick, of convenient length may be used. These strips shall be carefully set from curb to curb to the exact crown of the finished work, and embedded throughout their length in mortar, so that the top surface of the strips shall be the depth of the block below the grade of the finished surface, and not less on the average than ½ inch above the concrete. An iron-shod straight-edge or "striker" shall be drawn on the two sets of strips, set as above described, to strike the mortar bed to a true and even surface. Special care must be taken to produce a bed of uniform density. The mortar bed shall be showered with fresh mortar and struck off as many times as is necessary to produce a uniformly dense bed, free from depressions. As soon as a bed has been struck one set of strips shall be taken up, and the trench carefully filled with mortar.

7. Laying Blocks

Upon the mortar bed prepared as described above, the blocks shall be immediately laid with close joints and uniform top surface. The blocks shall be laid by the pavers standing upon the blocks already laid, and not upon the bed of mortar, and shall be laid at right angles with the lines of the curb, with such crown as is shown on the drawings, and in such a manner that all longitudinal joints shall be broken by a lap of approximately four inches. The blocks shall be laid so as to make the lateral joints as tight as possible, consistent with keeping a good alinement of the crosswise course, and where possible, the longitudinal joints shall be immediately closed by pressing each course in the direction of its length with a lever.

8. Joints

ASPHALT JOINTS.—As soon as practicable after laying the blocks, and making necessary corrections, the surface of the pavement shall be swept clean and hot asphalt applied with squeegee or other approved machine over the entire area. This asphalt shall have a melting point, ring and ball, of not less than 80 deg. Fahr. and in all other respects shall comply with the requirements of the American Wood Preservers' Association for asphaltic cement except for penetration. It shall be heated to a sufficient temperature without burning, to run freely into the joints, and leave as little as possible on the surface of the blocks. A thin layer of clean, coarse sand or stone screenings passing a ¼ inch screen shall immediately be spread over the pavement surface and left until the joints are entirely filled with sand and asphalt worked in by the action of traffic.

Sand Joints.—After the blocks have been laid the pavement shall be covered with fine, clean, dry sand which shall be thoroughly swept into the joints. The excess sand shall then be removed from the surface of the pavement and a squeegee coat of bitumen shall be applied in such manner as to insure the sealing of the joints and the coating of the surface.

Grout Joints.—After the mortar bed has taken its initial set, the joints shall be filled with a thin grout mixed in the proportions of 1 part cement to 1½ parts of fine sand.

The sand joint is the method most generally used for 2 inch and 2½ inch blocks. For the 1¼ inch block the joint should be either grouted or filled with asphalt. It is recommended that the asphalt filled joint be used for all sizes of blocks when used for pavement and for installations exposed to the weather.

9. Surfacing

The surfaces shall remain at a constant level, all edges of the blocks shall be flush with other edges at the same joint, and if they are not laid to meet this condition, the finished surface shall be ground by machines similar to those used for grinding terrazzo, the grinding medium being a No. 20 or 30 carborundum block. This grinding will be done as an alternative to lifting and re-laying and the decision as to which method to use will be at the direction of the Engineer.

10. Adjusting Existing Structures

Manholes and catchbasin covers, valve boxes, and similar existing structures within the area to be paved shall be adjusted by the Contractor to come flush with the pavement surface.

11. Guarantee

It is hereby understood and agreed that the Contractor shall guarantee the material furnished and used and the workmanship employed in the construction of the work, to be of such quality and character as to insure the same to be free from all defects, and to remain in continuous good order and condition satisfactory to the Engineer for a period of one year. The guarantee shall include all repairs to be made or, if necessary, the entire reconstruction of the work, as the Engineer may direct, without additional charge or cost to the Railroad Company.

12. General Conditions

All material entering into this work, and all methods used by the Contractor, shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this specification.

Section 25-B

[43]ASPHALT BLOCK FLOORS

1. General

The Contractor shall furnish all labor, material, tools and equipment, except as otherwise noted, necessary to entirely complete the asphalt block flooring as hereinafter specified, and as shown or implied on the drawings.

2. Description

The floor shall consist of a subgrade, a concrete foundation and asphalt blocks laid thereon in a mortar bed.

3. Subgrade and Foundation

The subgrade, if one be needed, and the foundation shall be designed of sufficient strength to carry the loading to be encountered, and shall be constructed in accordance with the current specifications of the A.R.E.A. for Concrete for railway buildings as given in Section 4 of these specifications, except that the concrete shall be finished to a smooth even surface, with no projections of any kind, parallel to the contour of and exactly the depth below the finished floor level, corresponding to the combined depth of the block and the thickness of the mortar bed used.

4. Blocks

Asphalt blocks shall be of .... make compressed to at least 4000 lb. per square inch at 225 deg. Fahr. Blocks shall be 5 inches in width, 12 inches in length unless the depth required is less than 2 inches, in which case they shall be 4 inches in width by 8 inches in length. The depth shall be shown on the drawings. A variation either way from these dimensions of ¼ inch in length or ⅛ inch in width or depth will be sufficient cause for rejection of any block.

5. Mortar Bed

There shall be placed upon the surface of the foundation, which is to be cleaned and wetted, a bed of cement mortar ½ inch in thickness. This mortar bed shall be composed of Portland cement and clean, sharp sand, which shall be free from pebbles over ¼ inch in diameter. The mortar shall be made in proportions of one part cement to four parts of sand. The ingredients shall be mixed with good clean water to such consistency that it can easily be spread upon the surface and struck with template to a smooth and even face. It must not, however, be so thin as to allow the blocks to sink into the mortar when placed thereon. This mortar shall be struck to a true surface exactly parallel to the top of the finished floor and the required depth of the block below it, in the following manner.

On the surface of the foundation shall be set strips of wood 4 inches wide by ¼ inch thick, and of a convenient length, or strips of metal 4 inches wide by ⅛ inch or $\frac{3}{16}$ inch thick, of convenient length may be used. These strips shall be carefully set from curb to curb to the exact crown of the finished work, and embedded throughout their length in mortar, so that the top surface of the strips shall be the depth of the blocks below the grade of the finished surface, and not less on the average than ½ inch above the concrete. An iron-shod straight-edge or "striker" shall be drawn on the two sets of strips, set as above described, to strike the mortar bed to a true and even surface. Special care must be taken to produce a bed of uniform density. The mortar bed shall be showered with fresh mortar and struck off as many times as is necessary to produce a uniformly dense bed, free from depressions. As soon as a bed has been struck one set of strips shall be taken up, and the trench carefully filled with mortar.

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[43] Adopted, Vol. 29, 1928, p. 957; Vol. 30, 1929, p. 1470.

6. Laying Blocks

Upon the mortar bed prepared as described above, the blocks shall be immediately laid with close joints and uniform top surface. The blocks shall be laid by the workmen standing upon the blocks already laid, and not upon the bed of mortar, and shall be laid at right angles with the longitudinal axis of building with such crown as is shown on the drawings, and in such a manner that all longitudinal joints shall be broken by a lap of approximately four inches. The blocks shall be laid so as to make the lateral joints as tight as possible, consistent with keeping a good alinement of the cross-wise course, and where possible, the longitudinal joints shall be immediately closed by pressing each course in the direction of its length with a lever.

7. Joints

ASPHALT JOINTS.—As soon as practicable after laying the blocks, and making necessary corrections, the surface of the floor shall be swept clean and hot asphalt applied with squeegee or other approved machine over the entire area. This asphalt shall have a melting point, ring and ball, of not less than 80 deg. Fahr. and in all other respects shall comply with the requirements of the American Wood Preservers' Association for asphaltic cement except for penetration. It shall be heated to a sufficient temperature without burning, to run freely into the joints, and leave as little as possible on the surface of the blocks. A thin layer of clean, coarse sand or stone screenings passing a ¼ inch screen shall immediately be spread over the floor surface and left until the joints are entirely filled with sand and asphalt worked in by the action of traffic.

SAND JOINTS.—After the blocks have been laid the floor shall be covered with fine, clean, dry sand which shall be thoroughly swept into the joints. The excess sand shall then be removed from the surface of the floor and a squeegee coat of bitumen shall be applied in such manner as to insure the sealing of the joints and the coating of the surface.

GROUT JOINTS.—After the mortar bed has taken its initial set, the joints shall be filled with a thin grout mixed in the proportions of 1 part cement to 1½ parts of fine sand.

The sand joint is the method most generally used for 2 inch and 2½ inch blocks. For the 1¼ inch block the joint should be either grouted or filled with asphalt. It is recommended that the asphalt filled joint be used for all sizes of blocks when used for pavement and for installations exposed to the weather.

8. Surfacing

The surface shall remain at a constant level, all edges of the blocks shall be flush with other edges at the same joint, and if they are not laid to meet this condition, the finished surface shall be ground by machines similar to those used for grinding terrazzo, the grinding medium being a No. 20 or 30 carborundum block. This grinding will be done as an alternative to lifting and re-laying and the decision as to which method to use will be at the direction of the Engineer.

9. Guarantee

It is hereby understood and agreed that the Contractor shall guarantee the material furnished and used and the workmanship employed in the construction of the work, to be of such quality and character as to insure the same to be free from all defects, and to remain in continuous good order and condition satisfactory to the Engineer for a period of one year. The guarantee shall include all repairs to be made or, if necessary, the entire reconstruction of the work, as the Engineer may direct, without additional charge or cost to the Railroad Company.

10. General Conditions

All material entering into this work, and all methods used by the Contractor, shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this specification.

Section 26-A

[44]MACADAM PAVEMENTS

1. General

The Contractor shall furnish all labor, material, tools and equipment, except as otherwise noted, necessary to entirely complete the macadam paving as hereinafter specified and as shown or implied on the drawings.

2. Description

The pavement shall consist of a subgrade and three courses of broken stone with proper binder; viz., a foundation course 6 inches in depth, a second course 4 inches in depth, and a top surface screenings course ⅜ inch in depth with curb or combined curb and gutter for pavement as shown on drawings.

3. Grading and Subgrade

Grading and subgrade shall be constructed in accordance with the current specification of the A.R.E.A. for Concrete Pavements.

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[44] Adopted, Vol. 29, 1928, p. 960; Vol. 30, 1929, p. 1470.

4. Curb and Gutter

The curb or the curb and gutter shall be built in the location and to the elevation, sizes and cross-section shown on drawings.

All cement and concrete materials and workmanship shall comply with the specifications for Concrete as given in Section No. 4 of these specifications. Not more than seven (7) gallons of water shall be used to each sack of cement.

5. Stone for Pavement

Stone and screenings shall be of hard and compact texture and of uniform grade. The fragments shall approach the shape of a cube as nearly as possible and have rough surfaces such as are obtained by fracture. Waterworn pebbles will not be accepted. Disintegrated and rotten stone from the surface of quarry will not be accepted. All stone shall be thoroughly cleaned before crushing and must be well screened and free from injurious matter of every nature. The Contractor shall state in his proposal at what quarries he is to secure stone.

6. Roller

The roller shall be self-propelled and weigh not less than ten tons.

7. Foundation Course

Upon the subgrade prepared in the manner above described shall be spread a layer of broken stone which, when thoroughly compacted, shall not be less than 6 inches in thickness. The stone shall be broken so as to measure not more than 2 inches and not less than 1 inch in any dimension. After this stone is spread, screenings, which shall pass through a ½ inch mesh, shall be swept into the interstices with rattan or steel brooms. In no case shall the screenings be dumped onto the course but shall be spread with a shovel.

The surface shall then be rolled and screenings spread until the interstices are apparently filled. Then the surface shall be rolled and sprinkled and screenings spread until all the interstices are filled and the stones do not creep or weave in front of the roller. The roller shall begin at the outer edge of the pavement, run parallel to the center line of the roadway and work towards the center. When the center is reached the roller shall begin at the other edge and again work towards the center. When there is a shoulder care shall be taken not to crush same by overlapping the stone with the roller. If any depressions occur, they shall be filled with stones of the specified size (not screenings) and rolled. No surplus screenings shall remain on the surface.

8. Second Course

On the foundation course prepared in the above described manner shall then be spread a layer of broken stone which, when thoroughly compacted, shall be at least 4 inches in thickness. The stone shall be broken so as to measure not more than one inch nor less than ½ inch in any dimension. The surface shall be rolled dry. Screenings shall then be spread and swept into the interstices as described for the foundation course excepting that no water shall be used. The screenings shall pass through a ½ inch mesh.

The rolling and spreading shall continue until all interstices are filled and the stones do not crawl or weave in front of the roller. The roller shall work in the manner described for the foundation course excepting that where there is a shoulder the rear wheel of the roller should be half on the shoulder and half on the stone when starting at the outer edge. If any depressions occur, they shall be filled with stone of the specified size (not with screenings) and the surface rolled.

9. Top Surface Screenings

On the surface of the second course prepared in the above described manner shall be spread a layer of screenings which shall entirely cover the surface with a coat approximately 3/8 inch thick when thoroughly compacted. The screenings shall pass through a 1/2 inch mesh. The screenings shall be sprinkled until thoroughly wet and then rolled, the roller keeping immediately behind the sprinkler. The rolling should continue until a grout is formed and a wave of grout continually forms in front of the roller. Screenings should not be dumped on the second course but should be placed at one side and spread over the surface with shovels. After the rolling is finished, the pavement shall be closed to traffic until the surface is thoroughly dry.

10. Adjusting Existing Structures

Manhole and catchbasin covers, valve boxes and similar existing structures within the area to be paved shall be adjusted by the Contractor to come flush with the surface of the pavement.

11. Guarantee

It is hereby understood and agreed that the Contractor shall guarantee the material furnished and used and the workmanship employed in the construction of said improvements, to be of such quality and character as to insure the same to be free from all defects, and to remain in continuous good order and condition satisfactory to the Engineer of the Railroad Company as above set forth for a period of two (2) years. The guarantee shall include all repairs to be made or, if necessary, the entire reconstruction of the work, as the Engineer of the Railroad Company may direct, without additional charge or cost to the Railroad Company.

In case the paving or any part thereof is on public property where city ordinance or other ruling requires a maintenance bond, the Contractor shall furnish within 10 days after the contract is let, a good and satisfactory bond to the amount as stated in the general contract to maintain that portion of the work on said public property as covered by this contract at the finished line and grade for a period of years as required by ordinance or ruling.

12. General Conditions

All materials entering into the work, and all methods used by the Contractor, shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this specification.

Section 26-B

[45]ASPHALT MACADAM PAVEMENTS

1. General

The Contractor shall furnish all labor, material, tools and equipment, except as otherwise noted, necessary to entirely complete the asphalt macadam paving as hereinafter specified and as shown or implied on the drawings.

2. Description

The pavement shall consist of a subgrade and two courses of broken stone with proper binder, viz., a base course 6 inches in depth and a wearing course 4 inches in depth with curb or combined curb and gutter as shown on drawings. The wearing course shall have asphalt cement binder.

3. Grading and Subgrade

Grading and subgrade shall be constructed in accordance with the current specification of the A.R.E.A. for Concrete Pavements.

4. Curb and Gutter

The curb or the curb and gutter shall be built in the location and to the elevation, sizes and cross-section shown on drawings.

All cement and concrete materials and workmanship shall comply with the specifications for Concrete as given in Section No. 4 of these specifications. Not more than seven (7) gallons of water shall be used to each sack of cement.

5. Stone for Pavement

Broken stone and screenings shall be of hard and compact texture and of uniform grade. The fragments shall approach the shape of a cube as nearly as possible and have rough surfaces such as are obtained by fracture. Waterworn pebbles will not be accepted. Disintegrated and rotten stone from the surface of quarry will not be accepted. All stone shall be thoroughly cleaned before crushing and must be well screened and free from injurious matter of every nature. The Contractor shall state in his proposal at what quarries he is to secure stone.

6. Asphalt Cement Binder

The asphaltic cement shall meet the requirements of the American Society for Testing Materials for asphalt cement of 100 to 120 penetration, Specification D-103-24T and current revisions thereof.

7. Roller

The roller shall be self-propelled and weigh not less than ten tons.

8. Foundation Course

Upon the subgrade prepared in the manner above described shall be spread a layer of broken stone which, when thoroughly compacted, shall not be less than 6 inches in thickness. The stone shall be broken so as to measure not more than 2 inches and not less than 1 inch in any dimension. After this stone is spread, screenings, which shall pass through a ½ inch mesh, shall be swept into the interstices with rattan or steel brooms. In no case shall the screenings be dumped onto the course but shall be spread with a shovel.

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[45] Adopted, Vol. 29, 1928, pp. 962, 1444; Vol. 30, 1929, p. 1470.

The surface shall then be rolled and screenings spread until the interstices are apparently filled. Then the surface shall be rolled and sprinkled and screenings spread until all the interstices are filled and the stones do not creep or weave in front of the roller. The roller shall begin at the outer edge of the pavement, run parallel to the center line of the roadway and work towards the center. When the center is reached the roller shall begin at the other edge and again work towards the center. When there is a shoulder care shall be taken not to crush same by overlapping the stone with the roller. If any depressions occur, they shall be filled with stones of the specified size (not screenings) and rolled. No surplus screenings shall remain on the surface.

9. Second Course

On the foundation course prepared in the above described manner shall then be spread a layer of broken stone which, when thoroughly compacted, shall be at least 4 inches in thickness. The stone shall be broken so as to measure not more than one inch nor less than ½ inch in any dimension. The surface shall be rolled dry. To each square yard of this layer shall be applied not less than 2¼ to 2½ gallons of asphalt cement binder in such manner that the stone is thoroughly and uniformly coated. The asphaltic cement shall be applied at a temperature of not less than 300 or more than 350 deg. Fahr. Screenings shall then be spread and swept into the interstices as described for the foundation course excepting that no water shall be used. The screenings shall pass through a ½ inch mesh. The rolling and spreading shall continue until all interstices are filled and the stones do not crawl or weave in front of the roller. The roller shall work in the manner described for the foundation course excepting that where there is a shoulder the rear wheel of the roller should be half on the shoulder and half on the stone when starting at the outer edge. If any depressions occur, they shall be filled with stone of the specified size (not with screenings) and the surface rolled.

10. Top Surface

The surface of the second course shall then be swept and any excess of stone removed. To each square yard of surface shall then be applied not less than ½ to ¾ gallon of asphaltic cement, and the surface again dressed with ⅛ to ⅜ inch stone chips or hard gravel, free from dust. Rolling with a steam roller shall then continue until the surface is true, uniform and compact.

The screenings shall pass through a ½ inch mesh.

The asphaltic cement shall be applied at a temperature of not less than 300 or more than 350 deg. Fahr.

11. Adjusting Existing Structures

Manhole and catchbasin covers, valve boxes and similar existing structures within the area to be paved shall be adjusted by the Contractor to come flush with the surface of the pavement.

12. Guarantee

It is hereby understood and agreed that the Contractor shall guarantee the material furnished and used and the workmanship employed in the construction of said improvements, to be of such quality and character as to insure the same to be free from all defects, and to remain in continuous good order and condition satisfactory to the Engineer of the Railroad Company as above set forth for a period of two (2) years. The guarantee shall include all repairs to be made or, if necessary, the entire reconstruction of the work, as the Engineer of the Railroad Company may direct, without additional charge or cost to the Railroad Company.

In case the paving or any part thereof is on public property where city ordinance or other ruling requires a maintenance bond, the Contractor shall furnish within 10 days after the contract is let, a good and satisfactory bond to the amount as stated in the general contract to maintain that portion of the work on said public property as covered by this contract at the finished line and grade for a period of years as required by ordinance or ruling.

13. General Conditions

All materials entering into the work, and all methods used by the Contractor, shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this specification.

Section 27

SPRINKLER SYSTEM

(In preparation.)

COMMITTEE VII

WOODEN BRIDGES AND TRESTLES

[1]DEFINITIONS

GENERAL

Wooden Trestle.—A wooden structure composed of upright members supporting simple horizontal members or beams, the whole forming a support for loads applied to the horizontal members.

Frame Trestle.—A structure in which the upright members or supports are framed timbers.

Pile Trestle.—A structure in which the upright members or supports are piles.

Bent.—The group of members forming a single vertical support of a trestle, designated as pile bent where the principal members are piles, and as framed bent where of framed timbers.

Post.—One of the vertical or battered members of the bent of a framed trestle.

Pile.—(See definitions under subject of Piles and Pile Driving.)

Batter.—A deviation from the vertical in upright members of a bent.

Cap.—A horizontal member on the top of piles or posts, connecting them to form a bent.

Sill.—The lowest horizontal member of a framed bent.

Mud-Sill or Sub-Sill.—A timber bedded in the ground to support a framed bent.

Intermediate Sill.—A horizontal member in the plane of the bent forming the cap of a lower section and the sill of an upper section.

Straight.—Having a right line axis.

Sway Brace.—A member bolted or spiked to the bent and extending diagonally across its face.

Longitudinal Strut or Girt.—A stiffening member running horizontally, or nearly so, from bent to bent.

Longitudinal X Brace.—A member extending diagonally from bent to bent in a vertical or battered plane.

Sash Brace.—A horizontal member secured to the posts or piles of a bent.

Stringer.—A longitudinal member extending from bent to bent and supporting the track.

Jack Stringer.—A stringer placed outside of the line of main stringers.

Brigde Tie.—A transverse timber resting on the stringers and supporting the rails.

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[1] Adopted, Vol. 6, 1905, pp. 35, 36, 42, 55-67; Vol. 7, 1906, pp. 683, 684; Vol. 11, Part 1, 1910, pp. 178, 228; Vol. 16, 1915, pp. 894, 1179; Vol. 21, 1920, pp. 1281, 1434; Vol. 23, 1922, pp. 708, 1148.

Inner Guard Rail.—A longitudinal member, usually a metal rail, secured on top of the ties inside of the track rail, to guide derailed car wheels.

Guard Timber.—A longitudinal timber placed outside of the track rail, to maintain the spacing of the ties.

Packing Block.—A small member, usually wood, used to secure the parts of a composite member in their proper relative positions.

Packing Spool of Separator.—A small casting used in connection with packing bolts to secure the several parts of a composite member in their proper relative positions.

Drift Bolt.—A piece of round or square iron of specified length, with or without head or point, driven as a spike.

Dowel.—An iron or wooden pin, extending into, but not through, two members of the structure to connect them.

Shim.—A small piece of wood or metal placed between two members of a structure to bring them to a desired relative elevation.

Fish-Plate.—A short piece lapping a joint, secured to the side of two members, to connect them end to end.

Bulkhead.—Timbers placed against the embankment side of an end bent to retain the embankment.

Ballast Curb.—A longitudinal timber placed along the outer edge of the floor on ballast deck bridges to retain the ballast.

[2]PILES AND PILE DRIVING

Pile.—A member usually driven or jetted into the ground and deriving its support from the underlying strata, and by the friction of the ground on its surface.

The usual functions of a pile are: (a) To carry a superimposed load; (b) To compact the surrounding ground; (c) To form a wall to exclude water and soft material, or to resist the lateral pressure of adjacent ground.

Head of Pile.—The upper end of a pile.

Foot of Pile.—The lower end of a pile.

Butt of Pile.—The larger end of a pile.

Tip of Pile.—The smaller end of a pile.

Bearing Pile.—One used to carry a superimposed load.

Screw Pile.—One having a broad-bladed screw attached to its foot to provide a larger bearing area.

Disc Pile.—One having a disc attached to its foot to provide a larger bearing area.

Batter Pile.—One driven at an inclination to resist forces which are not vertical.

Sheet Piles.—Piles driven in close contact in order to provide a tight wall, to prevent leakage of water and soft materials; or driven to resist the lateral pressure of adjacent ground.

Pile Driver.—A machine for driving piles.

Hammer.—A weight used to drive piles.

Drop Hammer.—One which is raised by means of a rope and then allowed to drop.

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[2] Adopted, Vol. 10, 1909, p. 565; Vol. 16, 1915, pp. 894, 1179; Vol. 21, 1920, pp. 1282, 1434.

Steam Hammer.—One which is automatically operated by the action of a steam cylinder and piston supported in a frame which rests on the pile.

Leads.—The upright parallel members of a pile driver which support the sheaves used to hoist the hammer and piles, and which guide the hammer in its movement.

Pile Cap, Hood or Bonnet.—A block used to protect the head of a pile and to hold it in the leads during driving.

Ring.—A metal hoop used to bind the head of a pile during driving.

Shoe.—A metal protection for the point or foot of a pile.

Follower.—A member interposed between the hammer and pile to transmit blows to the latter when below the foot of the leads.

[2]ECONOMICS

CAPITALIZATION METHOD—COMPARATIVE ECONOMIC VALUE—BALLAST DECK TRESTLES

Analysis No. 1

w = Cost of Wooden Trestle.
c = Cost of Concrete Trestle.
r = Rate of interest.
m = Life in years of wooden trestle.
n = " " " " concrete "
x = Amount capitalized which will replace wooden trestle every m years.
y = " " " " " concrete " " n "
f = Ratio of first cost of concrete trestle to first cost of wooden trestle to produce equal ultimate economy, that is

$f = \frac{c}{w}$ or $fw = c$

Then $x(1+r)^m = w + x$ and $y(1+r)^n = c + y$, whence $x = \frac{w}{[(1+r)^m - 1]}$

and $y = \frac{c}{[(1+r)^n - 1]} = \frac{fw}{[(1+r)^n - 1]}$

To produce equivalent ultimate economy $w + x = c + y$, which by substituting values of x and y gives

$$w + \frac{w}{[(1+r)^m - 1]} = fw + \frac{fw}{[(1+r)^n - 1]}$$

Dividing by w and solving for f it is found that

$$f = \frac{1 + \frac{1}{[(1+r)^m - 1]}}{1 + \frac{1}{[(1+r)^n - 1]}}$$

which is variable only with respect to m and n the assumed lives of wood and concrete. By using as an argument first cost of wooden trestle with a constant life regardless of such cost, the first cost of a concrete trestle with a life of n years is found by applying to cost of wooden trestle the coefficient f determined for n years.

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[2] Adopted, Vol. 19, 1918, pp. 593, 1223.

SINKING FUND METHOD—COMPARATIVE ECONOMIC VALUE —BALLAST DECK TRESTLES

Analysis No. 2

W = Cost of Wooden Trestle.

C = Cost of Concrete Trestle.

r = Rate of Interest on Cost of Trestle.

r' = " " " earned by Sinking Fund.

m = Life, in years, of Wooden Trestle.

n = " " " " Concrete "

a = Annual Contribution to Sinking Fund required to reproduce wooden trestle at end of m years.

b = Wr = Annual interest on original cost of Wooden Trestle.

d = Annual Contribution to Sinking Fund required to reproduce concrete trestle at end of n years.

e = Cr = Annual interest on original cost of Concrete Trestle.

E = a+b = Annual expense of wooden trestle.

E = d+e = " " " concrete "

F = Ratio of first cost of concrete trestle to first cost of wooden trestle to produce equal ultimate economy; that is

$F = \frac{C}{W}$ or $FW = C$

Then $E = Wr + \frac{W}{(1+r')^{m-1} + (1+r')^{m-2} \ldots\ldots + 1}$

and $E' = Cr + \frac{C}{(1+r')^{n-1} + (1+r')^{n-2} \ldots\ldots + 1}$

To produce equal economy $E = E'$ and by substituting values of E, E' and C and solving for F.

$$= \frac{r + \frac{1}{(1+r')^{m-1} + (1+r')^{m-2} + 1}}{r + \frac{1}{(1+r')^{n-1} + (1+r')^{n-2} + 1}} = \frac{r + \cfrac{}{\cfrac{(1+r')^{m}-1}{(1+r')-1}}}{r + \cfrac{1}{\cfrac{(1+r')^{n}-1}{(1+r')-1}}} = \frac{r + \frac{r'}{(1-r')^{m}-1}}{r + \frac{r'}{(1+r')^{n}-1}}$$

COMPARISON OF METHODS—COMPARATIVE ECONOMIC VALUE—BALLAST DECK TRESTLES

Analysis No. 3

W = Cost of Wooden Trestle.
C = Cost of Concrete Trestle.
r = Rate of Interest on Cost of Trestle.
r' = " " " earned by Sinking Fund.
m = Life, in years, of Wooden Trestle.
n = " " " " Concrete Trestle.
f = Ratio of first cost of Concrete Trestle to first cost of Wooden Trestle to produce equal ultimate economy by capitalization method, that is

$$f = \frac{C}{W} \text{ or } fW = C$$

F = Ratio of first cost of Concrete Trestle to first cost of Wooden Trestle to produce equal ultimate economy by sinking fund method, that is

$$F = \frac{C}{W} \text{ or } FW = C$$

By capitalization method
$$f = \frac{1 + \frac{1}{(1+r)^m - 1}}{1 + \frac{1}{(1+r)^n - 1}} \qquad (1)$$

By sinking fund method
$$F = \frac{r + \frac{r'}{(1+r')^m - 1}}{r + \frac{r'}{(1+r')^n - 1}} \qquad (2)$$

A comparison shows the two methods to be identical if same rate of interest is earned on sinking fund as that paid on cost of trestle, for in that case $r' = r$ and by substituting r for r' in (2) it becomes

$$F = \frac{1 + \frac{1}{(1+r)^m - 1}}{1 + \frac{1}{(1+r)^n - 1}} \qquad (3)$$

which is identical with (1) and $f = F$ It is therefore evident that regardless of what rate of interest is used the two methods are productive of the same results provided only that the same rate of interest be applied to sinking fund as to original cost of trestle.

REPLACEMENT METHOD—COMPARATIVE ECONOMIC VALUE —BALLAST DECK TRESTLES

Analysis No. 5

w = Cost of Wooden Trestle.
c = " " Concrete "
r = Rate of Interest
m = Life in years of Wooden Trestle.
n = " " " " Concrete "
A = Cost of Wooden Trestle for a period of n years.
B = " " Concrete " " " " " n "
f' = Ratio of first cost of concrete trestle to first cost of wooden trestle to produce equal ultimate economy, that is
$f' = \frac{c}{w}$ or $f'w = c$

Then $A = w\left[(1+r)^m + (1+r)^{2m} \ldots\ldots + (1+r)^{n-2m} + (1+r)^{n-m} + (1+r)^n\right] = w\frac{(1+r)^{n+m}-(1+r)^m}{(1+r)^m-1}$

and $B = c(1+r)^n$

To produce equivalent ultimate economy $A = B$, which by substituting values of A, B and c gives

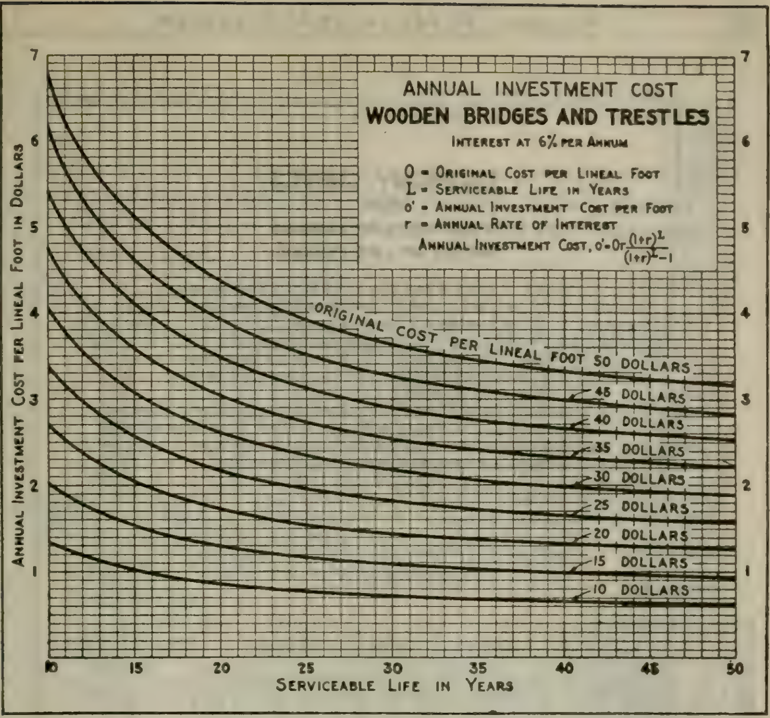
$$f'w(1+r)^n = w\,\frac{(1+r)^{n+m}-(1+r)^m}{(1+r)^m-1}$$

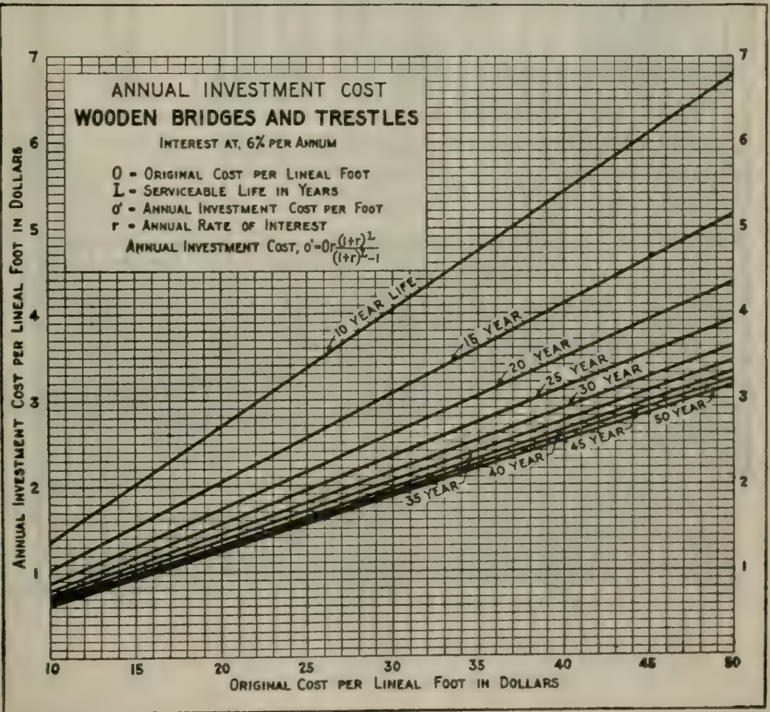
Dividing by w and solving for f' it is found that

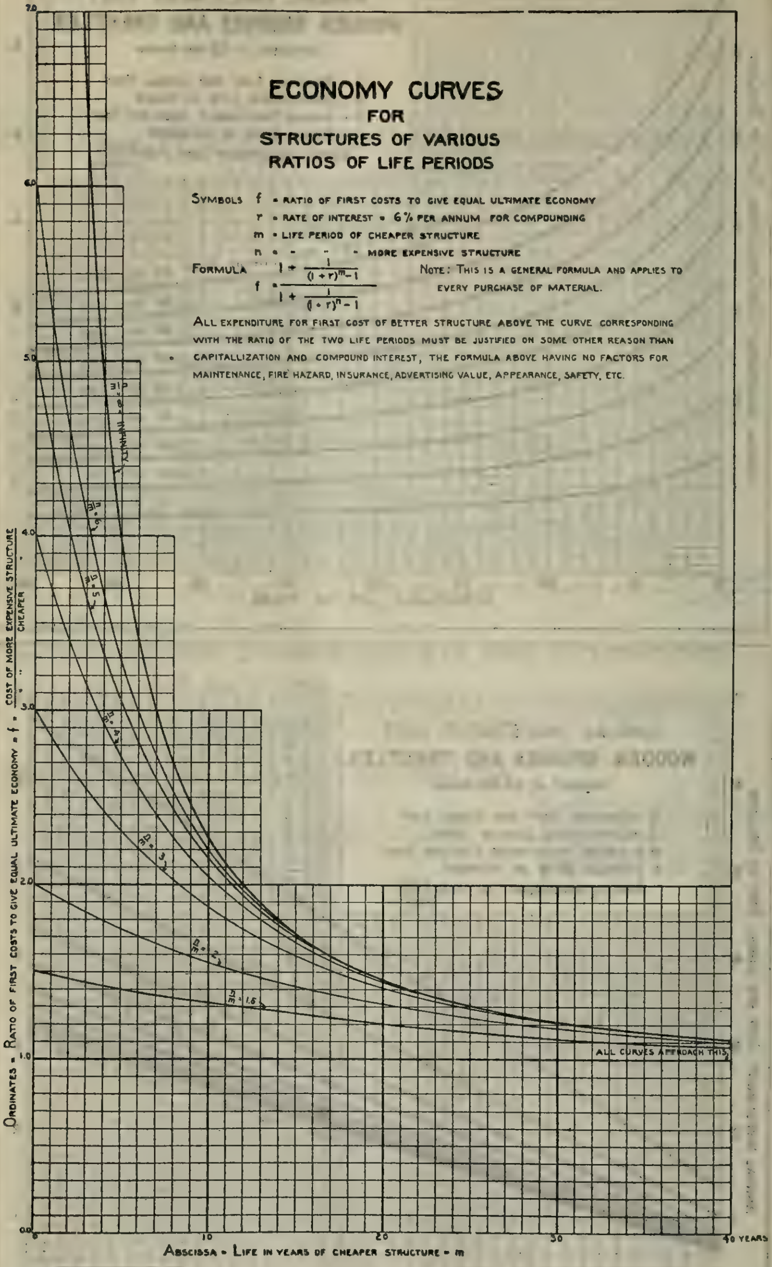
$$f' = \frac{\dfrac{(1+r)^{n+m}-(1+r)^m}{(1+r)^m-1}}{(1+r)^n} = \frac{(1+r)^{n+m}-(1+r)^m}{(1+r)^{n+m}-(1+r)^n} = \frac{\dfrac{(1+r)^{n+m}-(1+r)^m}{\left[(1+r)^n-1\right]\left[(1+r)^m-1\right]}}{\dfrac{(1+r)^{n+m}-(1+r)^n}{\left[(1+r)^n-1\right]\left[(1+r)^m-1\right]}}$$

$$= \frac{\dfrac{(1+r)^m}{(1+r)^m-1}}{\dfrac{(1+r)^n}{(1+r)^n-1}} = \frac{1+\dfrac{1}{(1+r)^m-1}}{1+\dfrac{1}{(1+r)^n-1}}$$

which is identical to the value of f in the Capitalization Method


ANNUAL INVESTMENT COST
WOODEN BRIDGES AND TRESTLES
INTEREST AT 6% PER ANNUM
O = ORIGINAL COST PER LINEAL FOOT
L = SERVICEABLE LIFE IN YEARS
o' = ANNUAL INVESTMENT COST PER FOOT
r = ANNUAL RATE OF INTEREST
ANNUAL INVESTMENT COST, $o' = Or\frac{(1+r)^L}{(1+r)^L-1}$
ORIGINAL COST PER LINEAL FOOT 50 DOLLARS
45 DOLLARS
40 DOLLARS
35 DOLLARS
30 DOLLARS
25 DOLLARS
20 DOLLARS
15 DOLLARS
10 DOLLARS
ANNUAL INVESTMENT COST PER LINEAL FOOT IN DOLLARS
1
2
3
4
5
6
7
10
15
20
25
30
35
40
45
50
SERVICEABLE LIFE IN YEARS


ANNUAL INVESTMENT COST
WOODEN BRIDGES AND TRESTLES
INTEREST AT 6% PER ANNUM
O = ORIGINAL COST PER LINEAL FOOT
L = SERVICEABLE LIFE IN YEARS
o' = ANNUAL INVESTMENT COST PER FOOT
r = ANNUAL RATE OF INTEREST
ANNUAL INVESTMENT COST, $o' = Or\frac{(1+r)^L}{(1+r)^L-1}$
10 YEAR LIFE
15 YEAR
20 YEAR
25 YEAR
30 YEAR
35 YEAR
40 YEAR
45 YEAR
50 YEAR
ANNUAL INVESTMENT COST PER LINEAL FOOT IN DOLLARS
1
2
3
4
5
6
7
10
15
20
25
30
35
40
45
50
ORIGINAL COST PER LINEAL FOOT IN DOLLARS



ECONOMY CURVES
FOR
STRUCTURES OF VARIOUS
RATIOS OF LIFE PERIODS

SYMBOLS f = RATIO OF FIRST COSTS TO GIVE EQUAL ULTIMATE ECONOMY
r = RATE OF INTEREST = 6% PER ANNUM FOR COMPOUNDING
m = LIFE PERIOD OF CHEAPER STRUCTURE
n = " " " MORE EXPENSIVE STRUCTURE

FORMULA

$$f = \frac{1 + \frac{1}{(1+r)^m - 1}}{1 + \frac{1}{(1+r)^n - 1}}$$

NOTE: THIS IS A GENERAL FORMULA AND APPLIES TO EVERY PURCHASE OF MATERIAL.

ALL EXPENDITURE FOR FIRST COST OF BETTER STRUCTURE ABOVE THE CURVE CORRESPONDING WITH THE RATIO OF THE TWO LIFE PERIODS MUST BE JUSTIFIED ON SOME OTHER REASON THAN CAPITALLIZATION AND COMPOUND INTEREST, THE FORMULA ABOVE HAVING NO FACTORS FOR MAINTENANCE, FIRE HAZARD, INSURANCE, ADVERTISING VALUE, APPEARANCE, SAFETY, ETC.

COMPARATIVE COST OF INSTALLATION OF BALLAST DECK TRESTLES PER LINEAR FOOT TO PRODUCE EQUIVALENT ECONOMIC VALUE; INTEREST AT 6 PER CENT. PER ANNUM. ASSUMING CREOSOTED TIMBER TRESTLE WILL SERVE 20 YEARS.

Creosoted Timber Service Life 20 Years	Justifiable Expenditure for Concrete Serviceable for							
	30 Yrs.	40 Yrs.	50 Yrs.	60 Yrs.	70 Yrs.	80 Yrs.	90 Yrs.	100 Yrs.
$10 00	$12 00	$13 09	$13 74	$14 09	$14 28	$14 39	$14 46	$14 49
11 00	13 20	14 39	15 12	15 50	15 71	15 83	15 90	15 94
12 00	14 40	15 70	16 49	16 91	17 14	17 26	17 35	17 39
13 00	15 60	17 01	17 86	18 32	18 57	18 70	18 79	18 83
14 00	16 80	18 32	19 24	19 73	20 00	20 14	20 24	20 28
15 00	18 00	19 63	20 61	21 14	21 43	21 58	21 68	21 73
16 00	19 20	20 94	21 99	22 54	22 86	23 02	23 13	23 18
17 00	20 40	22 24	23 36	23 95	24 28	24 46	24 57	24 63
18 00	21 60	23 55	24 74	25 36	25 71	25 90	26 02	26 09
19 00	22 80	24 86	26 11	26 77	27 14	27 34	27 46	27 53
20 00	24 00	26 17	27 48	28 18	28 57	28 77	28 91	28 98

COMPARATIVE COST OF INSTALLATION OF BALLAST DECK TRESTLES PER LINEAR FOOT TO PRODUCE EQUIVALENT ECONOMIC VALUE; INTEREST AT 6 PER CENT. PER ANNUM. ASSUMING CREOSOTED TIMBER TRESTLE WILL SERVE 25 YEARS.

Creosoted Timber Service Life 25 Years	Justifiable Expenditure for Concrete Serviceable for							
	30 Yrs.	40 Yrs.	50 Yrs.	60 Yrs.	70 Yrs.	80 Yrs.	90 Yrs.	100 Yrs.
$10 00	$10 77	$11 74	$12 33	$12 64	$12 82	$12 91	$12 97	$13 00
11 00	11 84	12 91	13 56	13 91	14 10	14 20	14 27	14 30
12 00	12 92	14 09	14 80	15 17	15 38	15 49	15 56	15 60
13 00	14 00	15 26	16 03	16 44	16 66	16 78	16 86	16 90
14 00	15 07	16 44	17 26	17 70	17 94	18 07	18 16	18 20
15 00	16 15	17 61	18 50	18 96	19 23	19 36	19 45	19 50
16 00	17 23	18 79	19 73	20 23	20 51	20 65	20 75	20 80
17 00	18 31	19 96	20 96	21 49	21 79	21 94	22 05	22 10
18 00	19 38	21 13	22 19	22 76	23 07	23 24	23 34	23 40
19 00	20 46	22 31	23 43	24 02	24 35	24 53	24 64	24 70
20 00	21 54	23 48	24 66	25 29	25 63	25 82	25 94	26 00

RATIO OF INSTALLATION COSTS OF STRUCTURES TO PRODUCE EQUIVALENT ULTIMATE ECONOMY IN THEIR PERPETUAL MAINTENANCE. BASED ON AN INTEREST RATE OF 6 PER CENT. PER ANNUM FOR CAPITAL INVESTED THEREIN, AND NEGLECTING COSTS OF REPAIRS.

Service Life Years	5	10	15	20	25	30	40	50	60	70	80	90	100
100	3.94491	2.25779	1.71099	1.44880	1.29994	1.20725	1.10721	1.05429	1.02822	1.01422	1.00702	1.00234	1.00000
90	3.93569	2.25251	1.70699	1.44551	1.29690	1.20442	1.10462	1.05182	1.02582	1.01185	1.00467	1.00000	
80	3.91741	2.24205	1.69906	1.43869	1.29087	1.19883	1.09949	1.04694	1.02105	1.00715	1.00000		
70	3.88960	2.22613	1.68700	1.42848	1.28171	1.19032	1.09168	1.03951	1.01380	1.00000			
60	3.83663	2.19582	1.66403	1.40903	1.26426	1.17411	1.07682	1.02771	1.00000				
50	3.74177	2.14153	1.62288	1.37419	1.23300	1.14508	1.05019	1.00000					
40	3.56295	2.03918	1.54532	1.30852	1.17407	1.09035	1.00000						
30	3.26770	1 87020	1.41727	1.20008	1.07678	1.00000							
25	3.03470	1.73684	1.31621	1.11451	1.00000								
20	2.72290	1.55840	1.18098	1.00000									
15	2.30564	1.31958	1.00000										
10	1.74725	1.00000											
5	1.00000												

This statement is developed from formula in Analysis No. 1.

[3]RELATIVE MERITS OF OPEN AND BALLAST DECK TIMBER TRESTLES

(1) The open deck trestle has the advantage of the ballast deck in lower original cost, greater adaptability in temporary or emergency installations, and lower costs in effecting renewals under traffic.

(2) The principal advantages of the ballast deck trestle when compared with the open deck type are:

> Better protection against loss and damage and interruption in train service due to fire.
> Superior track riding qualities.
> More satisfactory and safer appearance.
> Greater serviceability and better performance when subjected to overload.
> Vastly less expensive to maintain.

(3) Because of the impossibility of segregating from operating expense accounts or allocating in operating revenue definite amounts resulting from the use of either type of structure, the true relative economy is not susceptible of mathematical demonstration.

(4) As a safeguard against serious error in adopting either type in any individual case, the following rule can be relied upon for conservatism:

> If the difference between the annual investment cost of the two types equals or only slightly exceeds the annual cost of maintenance of the open deck type, the ballast deck type will be the more economical.

[4]COMPARATIVE MERITS OF BALLAST DECK AND REINFORCED CONCRETE TRESTLES

(1) While in certain locations there is little probability of fire loss in creosoted ballast deck timber trestles, yet due to the very nature of the material used the reinforced concrete trestle has a decided advantage.

(2) The concrete structure is slightly superior to the timber structure for bridging waterways subject to flood currents, or wide fluctuations in elevation of water surface.

(3) Although the concrete trestle may possibly afford better service qualities than the wooden trestle, the matter is so intangible in character as to preclude a definite statement of relative merit.

(4) Where selection of type of trestle is optional and not influenced by other considerations, neither type of trestle has the advantage of the other in matter of appearance.

(5) Notwithstanding the fact that the two materials are, with certain limitations, equally suitable for the construction of trestles, the use of con-

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[3] Adopted, Vol. 24, 1923, pp. 773, 1199.

[4] Adopted, Vol. 19, 1918, pp. 592, 603, 1223.

crete is more in accord with the theory of conservation of natural resources and industrial economy.

(6) Adoption of either type should be the result of carefully weighing, for each individual bridge, the greater economy of the timber trestle against the several advantages of the concrete not susceptible of mathematical demonstration.

(7) Creosoted timber trestles are more economical than concrete, except when the cost of the concrete structure is less than one and one-half times the cost of the wooden structure.

[5]VALUE OF TREATED TIMBERS IN WOODEN BRIDGES AND TRESTLES

(1) Treated timber is more economical than untreated timber in wooden bridges and trestles and should be used for these structures except when the construction is temporary.

(2) Timbers which are to be creosoted should be completely framed before treatment. If it is necessary to cut or damage the surfaces after treatment, they should have several coats of hot creosote applied to protect them.

(3) If properly handled in the creosoting plants, the strength of the timber is not materially reduced and can be used with the same working stresses as untreated timber.

(4) The fire hazard is somewhat reduced, and if ballasted deck bridges are constructed of treated timber, the hazard from inflammatory material dropped from trains is nearly eliminated.

(5) Creosote in timber is not injurious to the metal fastenings.

(6) Sapwood when treated is preferable to heartwood. It is inherently as strong and takes the creosote more readily.

[6]BEST METHOD OF FIREPROOFING WOODEN BRIDGES AND TRESTLES

(1) All locomotives should have adequate and well-maintained spark screens in the front end and ashpans should be maintained with a tight fit so that fires and hot coals cannot drop out.

(2) The decks of wooden bridges should be protected from fires starting from hot coals dropped from locomotives, preferably by adopting ballasted deck trestles; otherwise, by covering the deck with rust resisting sheet metal or covering the stringers and caps with rust resisting sheet metal.

(3) When ties or other timbers are exposed, all decayed timbers should be kept trimmed off.

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[5] Adopted, Vol. 28, 1927, pp. 409, 1426.

[6] Adopted, Vol. 23, 1922, pp. 722, 1156.

(4) All brush and weeds should be kept down for a distance of at least 25 feet from the bridge, both underneath and on the embankment at the ends of the bridge. Also all sod should be removed from under timber bridges for a distance of three feet outside of the timber.

(5) Water barrels with buckets should be maintained on all timber bridges, one barrel each for structures up to 50 feet long and one additional barrel for each additional 150 feet.

(6) On long bridges it is advisable to protect the bridge by introducing fire barriers at intervals of about 400 feet. This will reduce the hazard by preventing loss of the entire structure in case of fire.

(7) Special fire fighting apparatus and watchman should be employed in unusual cases where conditions warrant.

[7]RELATIVE ECONOMY OF REPAIRS AND RENEWALS OF WOODEN BRIDGES AND TRESTLES

It is good practice to repair wooden bridges and trestles by parts until such time as the general condition of the structure requires entire renewal.

[8]USE OF GUARD RAILS AND GUARD TIMBERS FOR WOODEN BRIDGES AND TRESTLES

(1) It is recommended as good practice to use guard timbers on all open-floor bridges, and same should be so constructed as to properly space the ties and hold them securely in their places.

(2) It is recommended that the guard timber and the inner guard rail, when used, shall be so spaced in reference to the track rail that a derailed truck will strike the inner guard rail without striking the guard timber. The inner guard rail should not be higher nor more than one inch lower than the running rail.

(3) It is recommended as good practice in the installation of inner guard rails to extend them beyond the ends of the bridges for such distance as is required by local conditions, but that this distance, in any case, be not less than 50 feet; the inner guard rails be fully spiked to every tie, and spliced at every joint; that the inner guard rails be some form of metal section; and that the ends be beveled, bent down, or otherwise protected against direct impact with moving parts of equipment.

(4) It is recommended as good practice to use inner guard rails on all open-floor and on the outside tracks of all solid-floor bridges and similar structures longer than 20 feet in main-line tracks, and on similar bridges and structures in branch-line tracks on which the speed of trains is 20 miles per hour or more.

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[7] Adopted, Vol. 16, 1915, pp. 891, 1179.

[8] Adopted, Vol. 14, 1913, pp. 652, 653, 1136-1143; Vol. 15, 1914, pp. 403, 1036-1044; Vol. 21, 1920, pp. 1285, 1434.

[9]USE OF LAG SCREWS IN TRESTLE CONSTRUCTION

(1) Lag screws require greater care than ordinary bolts and nuts to properly install, but are cheaper on account of ease of general maintenance.

(2) Lag screws, where properly applied, hold ties from bunching equally as well as bolts and nuts, and better than daps, in guard timbers.

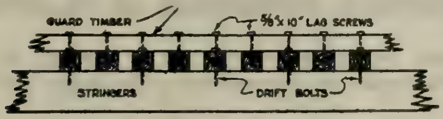
(3) If the lag screws are tightened after timber has shrunk, there is less cost of maintenance than with bolts and nuts.

(4) Use of lag screws renders unnecessary the dapping of guard timbers, and, therefore, decreases cost of trestles without impairing quality.

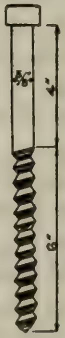
(5) Surfacing (sizing) ties and guard timbers is better construction than dapping.

(6) For proper application of lag screws, holes in guard timbers should be bored with auger bits 1/16 inch less in diameter and holes in ties ¼ inch less in diameter than the nominal size of lag screws used.

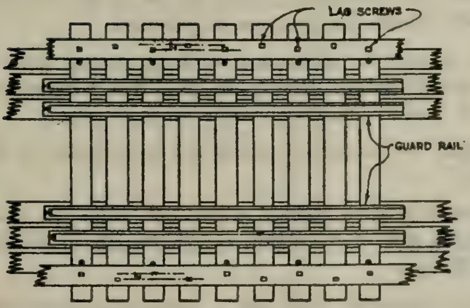
(7) Lag screws must be screwed in, not driven.



ELEVATION.



LAG SCREW.



PLAN

NOTE.—Ties and guard timbers to be sized one dimension. Omit dapping of guard timbers and ties. Use lag screws in every tie. Holes to be bored for lag screws one inch deeper than penetration of lag screws. Holes to be bored 1/16 inch smaller than diameter of lag in guard timber, and ¼ inch smaller than diameter of lag in ties. Lag screws must not be driven but screwed to position. Fasten alternate ties to stringers. Lag screws to be staggered 2 inches in guard timbers.

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[9]Adopted, Vol. 19, 1918, pp. 584, 608, 1225.

[10]PLANS FOR OPEN DECK PILE AND FRAME TRESTLES, MULTIPLE STORY TRESTLE, AND BALLAST DECK PILE AND FRAME TRESTLES

Open Deck Pile Trestle, Light Design, E-45 Loading, with panels 12, 14 and 16 feet long.

Open Deck Pile Trestle, Heavy Design, E-60 Loading, with panels 12, 14 and 16 feet long.

Open Deck Frame Trestle, Light Design, E-45 Loading, with panels 12, 14 and 16 feet long.

Open Deck Frame Trestle, Heavy Design, E-60 Loading, with panels 12, 14 and 16 feet long.

Multiple Story Trestle, E-60 Loading, with panels, 12, 14 and 16 feet long.

Ballast Deck Pile and Frame Trestles, Heavy Design, E-60 loading.

[11]PILE DRIVING—PRINCIPLES OF PRACTICE

(1) A thorough exploration of the soil by borings, or preliminary test piles, is the most important prerequisite to the design and construction of pile foundations.

(2) Soil consisting wholly or chiefly of sand is most favorable to the use of the water jet.

(3) In harder soils containing gravel the use of the jet may be advantageous, if sufficient volume and pressure be provided.

(4) In clay it may be economical to bore several holes in the soil with the aid of the jet before driving the pile, thus securing the accurate location of the pile, and its lubrication while being driven.

(5) In general, the water jet should not be attached to the pile, but handled separately.

(6) Two jets will often succeed where one fails. In special cases a third jet, extending a part of the depth, aids materially in keeping loose the material around the pile.

(7) Where the material is of such a porous character that the water from the jets may be dissipated and fail to come up in the immediate vicinity of the pile, the utility of the jet is uncertain, except for a part of the penetration.

(8) A steam or drop hammer should be used in connection with the water jet, and used to test the final rate of penetration.

(9) The use of the water jet is one of the most effective means of avoiding injury to piles by overdriving.

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[10] Adopted, Vol. 26, 1925, pp. 550, 1380.

[11] Adopted, Vol. 12, 1911, Part 1, pp. 279, 307; Vol. 16, 1915, pp. 894, 1181.

Comparison of Unit Stresses in Proposed Types of Standard Trestles

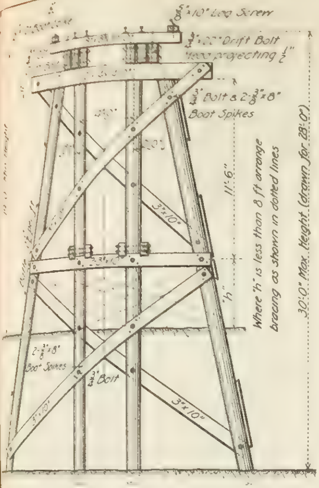
LOADINGS		Open Deck Trestles														Ballast Deck Trestle
		Cooper's E-45							Cooper's E-60							Coopers E-60
Length of Span in feet		12 Feet				14 Feet		16 Feet	12 Feet				14 Feet		16 Feet	13 Feet
Number and Size of Stringers		3-7"×14"	3-7½"×15"	3-7"×16"	3-8"×16"	3-8"×16"	3-9"×16"	3-9"×18"	4-7"×14"	4-7½"×15"	4-7"×16"	4-8"×16"	4-8×16"	4-9×16"	4-9"×18"	12-7"×16"
Reaction on Bents	Dead Load Per Track	7800	8200	8140	8530	10100	10500	12640	8640	9200	9150	9720	11340	12010	14600	32500
	Live Load	105100	105100	105100	105100	117400	117400	128000	140200	140200	140200	140200	156500	156500	170600	147840
	Total Load	112900	113300	113240	113630	127500	127500	140640	148840	149400	149350	149920	167840	168510	185200	180340
Kind of Bents		Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts	Piles / Posts
Bearing of Caps on Posts or Piles	Number of Posts or Piles	4 / 4	4 / 4	4 / 4	4 / 4	4 / 4	4 / 4	5 / 5	5 / 5	5 / 5	5 / 5	5 / 5	5 (6) / 5 (6)	5 (6) / 5 (6)	6 / 6	6 / 6
	Size	14'0 / 12×12	14'0 / 12×12"	14'0 / 12×12"	14'0 / 12×12	14'0 / 12×12"	14 0 / 12×12"	14 0 / 12×12	14'0 / 12×12"	14 0 / 12"×12"	14'0 / 12×12"	14'0 / 12"×12"	14 0 / 12×12	14 0 / 12"×12	14'0 / 12"×12"	14'0 / 12"×12"
	Area in Square Inches	616 / 576	616 / 576	616 / 576	616 / 576	616 / 576	616 / 576	770 / 720	770 / 720	770 / 720	770 / 720	770 / 720	770(924) / 720(864)	770(924) / 720(864)	924 / 864	924 / 864
	Unit Stress lbs per Sq Inch	183 / 196	184 / 197	184 / 197	184 / 197	207 / 221	208 / 222	183 / 195	193 / 207	194 / 208	194 / 208	195 / 208	218(182) / 233(194)	219(182) / 234(195)	200 / 214	195 / 209
	Load per Pile in Tons	141	142	142	142	159	158	141	149	149	149	150	168(140)	168(140)	15 5	15.0
Bearing of Stringers on Caps	Area in Sq Inches 12" Wide	504	540	504	576	576	648	648	672	720	672	768	768	864	864	1680
	14	588	630	588	672	672	756	756	784	840	784	896	896	1008	1008	1960
	Unit Stress, lbs per Sq In 12" Wide	224	210	224	215	221	197	217	221	208	222	195	219	195	214	107
	14"	192	180	193	169	190	169	186	189	178	190	167	187	167	184	92
Flexural Bending Stress	Weight of Rail etc per lin ft	213#	213#	213#	213#	213#	213#	213#	213#	213#	213#	213#	213#	213#	213#	977
	Stringers	110#	127#	126#	144#	144#	162#	182#	147#	169#	168#	192#	192#	216#	243#	273
Loads Moments and	Total Dead Load	323#	340#	339#	357#	357#	375#	395#	360#	382#	381#	405#	405#	429#	456#	1250
Section Moduli taken																
for One Rail only	Dead Load Moment, Inch lbs	69800	73440	73200	77100	105000	110300	151700	77800	82500	82300	87500	119100	126100	175100	316 872
	Live	1080000	1080000	1080000	1080000	1485000	1485000	1890000	1440000	1440000	1440000	1440000	1980000	1980000	2520000	1710720
	Total Moment	1149800	1153440	1153200	1157100	1590000	1595300	2041700	1517800	1522500	1522300	1527500	2099100	2106100	2695100	2027592
	Section Modulus "Nominal"	686	844	896	1024	1024	1152	1458	915	1125	1195	1365	1365	1536	1944	1494
	Bending Stress in Extreme Fibre	1676	1367	1287	1130	1553	1385	1400	1659	1353	1274	1119	1538	1371	1386	1357
	Section Modulus "Minimum"	638	789	837	961	961	1085	1378	851	1051	1116	1282	1282	1447	1838	1395
	Bending Stress in Extreme Fibre	1802	1462	1378	1204	1655	1470	1482	1784	1450	1364	1192	1637	1456	1466	1454
	Per Cent Efficiency	78	96	102	116	85	95	35	79	97	102	118	86	96	95	96
Longitudinal Shear, (First Driver at Quarter Point)																
	Dead Load each set Stringers	1000	1000	1000	1070	1300	1310	1600	1080	1150	1150	1220	1400	1500	1800	4062
Loads, and Sectional	Live Load	25800	25800	25800	25800	28125	28125	29900	34400	34400	34400	34400	37500	37500	39800	36060
Areas taken for One	Total Load	26800	26800	26800	26870	29425	29435	31500	35480	35550	35550	35620	38900	39 000	41600	40122
Rail only																
	Nominal Area Cross Sect □"	294	338	336	384	384	432	486	392	450	448	512	512	576	648	560
	Longitudinal Shear $H = \frac{3}{2}\frac{S}{A}$	137	119	120	105	115	102	97	136	119	119	104	114	102	96	107
	Minimum Area Cross Sect □"	278	321	319	366	366	413	466	371	428	425	488	488	551	621	532
	Longitudinal Shear $H = \frac{3}{2}\frac{S}{A}$	145	125	126	110	121	107	101	143	125	126	109	120	106	100	113
	Per Cent Efficiency Pine	86	100	99	114	103	117	123	88	100	99	114	104	118	125	111
	Douglas Fir	69	80	79	91	83	93	39	70	80	79	92	83	94	100	89

PERMISSIBLE WORKING STRESSES	DENSE PINE	DOUGLAS FIR
Extreme Fibre Stress in Bending	1400# per □"	1400# per □"
Compression across Grain	250# □"	250# □"
Shear across Grain	250# . □"	250# . □"
Longitudinal Shear	125# . □"	100# . □"

NOTE — Per cent efficiency for stringers $= \frac{\text{Permissible Unit Fiber Stress}}{\text{Computed Unit Fiber Stress}}$

Computed Unit Fiber Stress based on stringers ¼" less in depth and width than nominal sizes

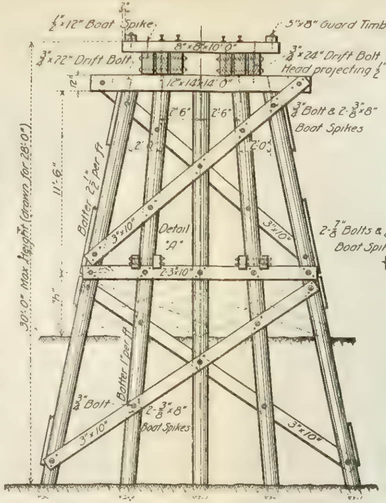
Ext Fiber Stress & Long. Shear based on Live Load carried by 10 Stringers



Typical 4 Pile Bent 19 ft to 30 ft.

12 & 14 ft Panel Lengths

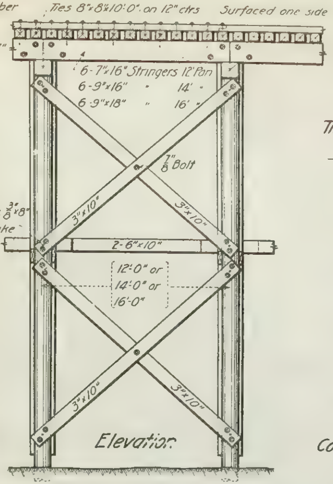
For heights over 30 ft. add one more sash brace 23'-6" below bottom of cap and corresponding sway braces



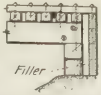
Typical 5 Pile Bent 19 ft. to 30 ft.

16 ft Panel Lengths

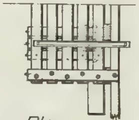
Bracing on 5 Pile bents 11 ft to 18 ft to be similar to bracing on 4 Pile bents, 11 ft to 18 ft. On bents less than 11 ft from B of R to ground omit sway bracing



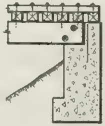
Elevation



Timber Bulkhead



Plan



Concrete Bulkhead

If desirable pile bents may be spaced 11'-9", 13'-9" and 15'-9" apart in order that standard length stringers may be used if bent spacing should be greater than intended, and to allow for increased length on curves

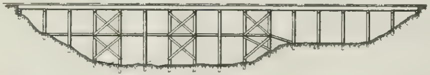
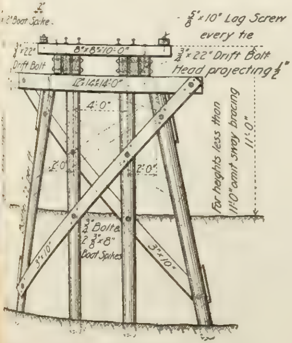


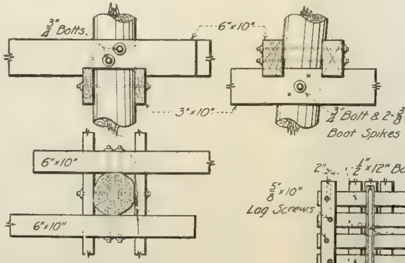
Diagram Showing Longitudinal Bracing

Trestles which are 100 ft or more in length and over 15 ft in height from Base of Rail to ground shall have longitudinal cross bracing every 2nd or 3rd Panel. Longitudinal girts must be carried to bank, and securely fastened to bent near ground line



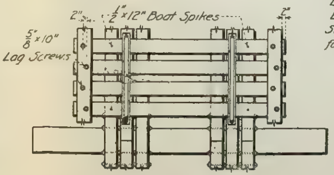
Typical 4 Pile Bent 11 ft. to 18 ft.

12 & 14 ft Panel Lengths



Detail at "A"

Note:
Dimensions of timbers are nominal sizes
Super-elevation for curves to be framed in piles.



Plan

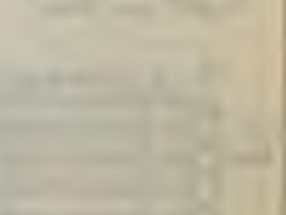
Permissible Working Stresses	-Dense Pine	-Douglas Fir
Extreme fibre stress in bending	1400# per □"	1400# per □"
Compression across grain	250# " □"	250# " □"
Longitudinal Shear	125# " □"	100# " □"
Load on piles (D+L)	15 Tons	

Stresses to be used without adding anything to live load for impact

RECOMMENDED PRACTICE
for
4 & 5 PILE, OPEN DECK TRESTLES
LIGHT DESIGN E45 LOADING
A.R.E.A

[illegible]

[illegible]



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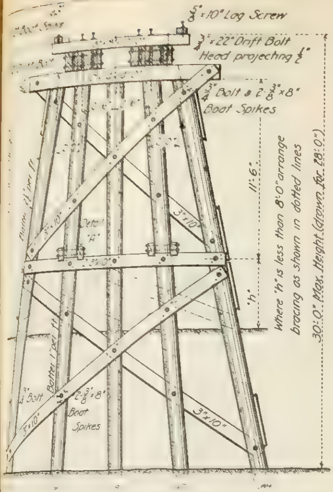
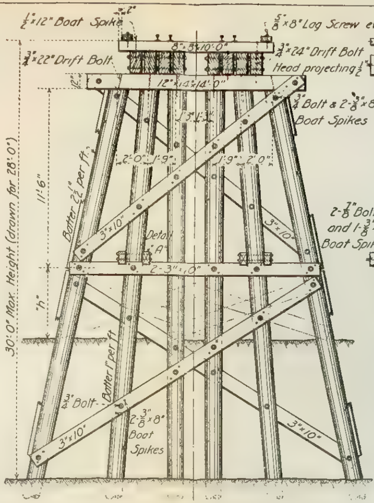

5/8"×10" Log Screw
3/4"×22" Drift Bolt Head projecting 1/2"
3/4" Bolt & 2-3/8"×8" Boat Spikes
11'-6"
"h"
Where "h" is less than 8'-0" arrange bracing as shown in dotted lines
30'-0" Max. Height (drawn for 28'-0")
Detail "A"
3"×10"
Batter 1" per ft
3/4" Bolt
2-3/8"×8" Boat Spikes

Typical 5 Pile Bent 19 ft. to 30 ft.

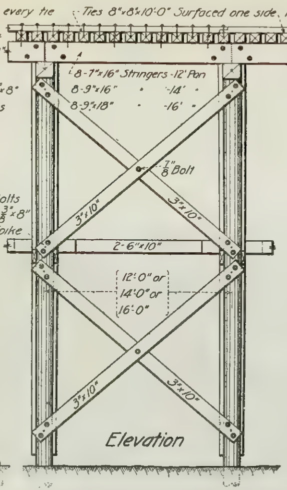
12 & 14 ft Panel Lengths

For heights over 30 ft add one more sash brace 23'-6" below bottom of cap and corresponding sway braces

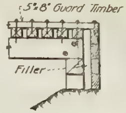


Typical 6 Pile Bent 19 ft to 30 ft

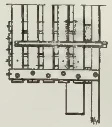
16 ft Panel Lengths

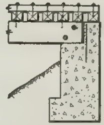

Ties 8"×8"×10'-0" Surfaced one side, 12" ctrs
8-7"×16" Stringers -12' Pan
8-9"×16" " -14' "
8-9"×18" " -16' "
7/8" Bolt
3"×10"
2-7/8" Bolts and 1-3/8"×8" Boat Spike
2-6"×10"
12'-0" or 14'-0" or 16'-0"
Elevation

If desirable pile bents may be spaced 11'-9", 13'-9" and 15'-9" apart in order that standard length stringers may be used if bent spacing should be greater than intended and to allow for increased length on curves



Timber Bulkhead





Concrete Bulkhead

Bracing on 6 Pile Bents 11 ft to 18 ft to be similar to bracing on 5 Pile Bents 11 ft to 18 ft. On bents less than 11 ft from Base of Rail to ground omit sway bracing

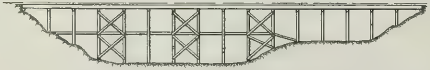
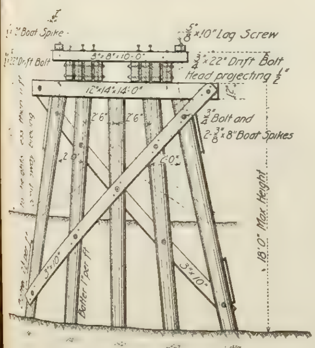


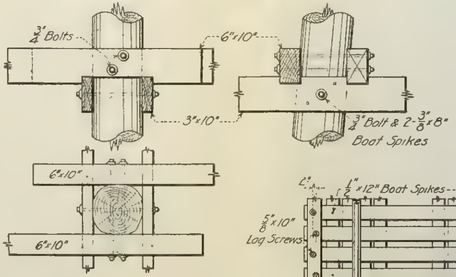
Diagram Showing Longitudinal Bracing

Trestles which are 100 ft or more in length and over 15 ft in height from Base of Rail to ground shall have longitudinal cross bracing every 2nd or 3rd panel. Longitudinal girts must be carried to bank and securely fastened to bent near ground line



Typical 5 Pile Bent 11 ft. to 18 ft.

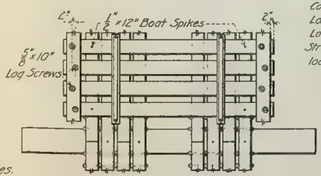
12 & 14 ft Panel Lengths



Detail at "A"

Note.

Dimensions of timbers are nominal sizes. Super-elevation for curves to be framed in piles

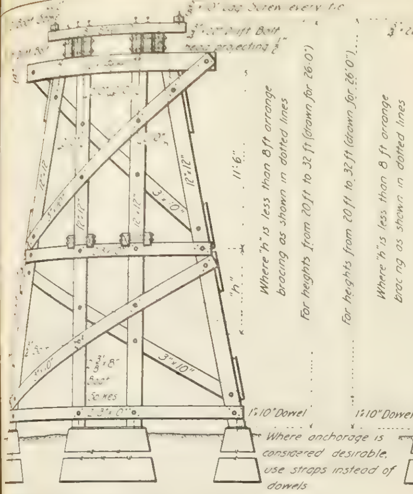


Plan

PERMISSIBLE WORKING STRESSES	DENSE PINE	- DOUGLAS FIR
Extreme fibre stress in bending	1400# per □"	- 1400# per □"
Compression across grain	250# " □"	250# " □"
Longitudinal Shear	125# " □"	100# " □"
Load on piles (D+L)	15 Tons	

Stresses to be used without adding anything to live load for Impact

RECOMMENDED PRACTICE
for
5 & 6 PILE OPEN DECK TRESTLES
HEAVY DESIGN E-60 LOADING
A. R. E. A.



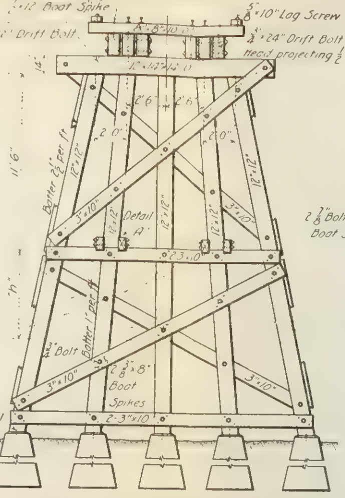
Lag Screw every tie
3/4"x22" Drift Bolt
Head projecting 1/2"
12"x12"
3"x10"
3/8"x8" Boat Spikes
2-3"x10"
11'-6"
"h"
Where "h" is less than 8 ft arrange bracing as shown in dotted lines
For heights from 20 ft to 32 ft (drawn for 26'-0")
1"x10" Dowel
Where anchorage is considered desirable, use straps instead of dowels

Typical 4 Post Bent 20 ft to 32 ft.

12 & 14 ft Panel Lengths

Foundation either piles or concrete

Continuous foundations may be used when local conditions justify

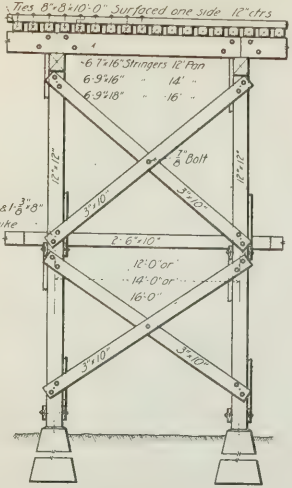


Typical 5 Post Bent 20 ft. to 32 ft.

16 ft Panel Lengths

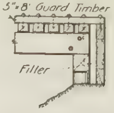
Foundation either piles or concrete

Sway bracing on 5 post bents up to 19 ft to be similar to bracing on 4 post bents up to 19 ft

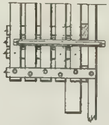


Ties 8"x8"x10'-0" Surfaced one side 12" ctrs
6-7"x16" Stringers 12' Pan
6-9"x16" " 14' "
6-9"x18" " 16' "
12"x12"
7/8" Bolt
3"x10"
2-7/8" Bolts & 1-3/8"x8" Boat Spike
2-6"x10"
12'-0" or
14'-0" or
16'-0"

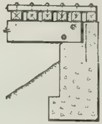
Elevation



Timber Bulkhead



Plan



Concrete Bulkhead

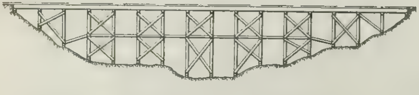
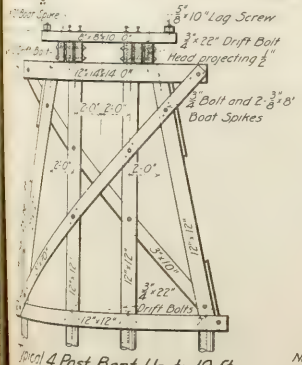


Diagram Showing Longitudinal Bracing

Frame trestles to have longitudinal bracing for all heights.

PERMISSIBLE WORKING STRESSES	- DENSE PINE	- DOUGLAS FIR
Extreme fibre stress in bending	1400# per □"	1400# per □"
Compression across grain	250# " □"	250# " □"
Longitudinal Shear	125# " □"	100# " □"
Load on piles (D+L)	15 Tons	

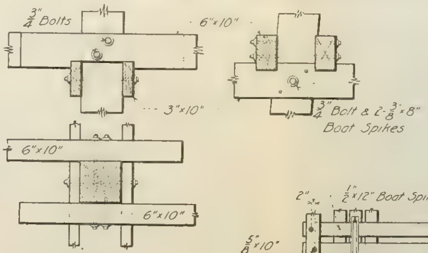
Stresses to be used without adding anything to live load for impact



Typical 4 Post Bent Up to 19 ft.

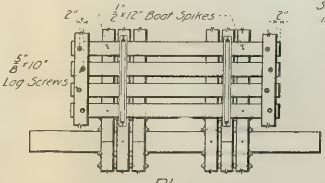
12 & 14 ft Panel Lengths

Foundation either piles or concrete



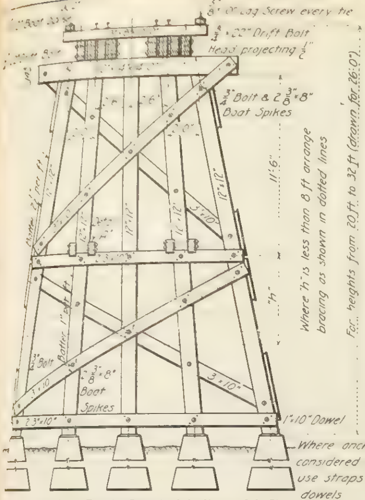
Detail at "A"

Note:
Dimensions of timbers are nominal sizes
Super-elevation for curves to be framed in posts



Plan

RECOMMENDED PRACTICE
for
OPEN DECK FRAME TRESTLE
LIGHT DESIGN - E45 LOADING
A R E A



$\frac{5}{8}$"×10" Lag Screw every tie
$\frac{3}{4}$"×22" Drift Bolt
Head projecting $\frac{1}{2}$"
$\frac{3}{4}$" Bolt & 2-$\frac{3}{8}$"×8"
Boat Spikes
2'-6"
2'-0"
Batter 2$\frac{1}{2}$" per ft
12"×12"
3"×10"
11'-6"
"h"
Where "h" is less than 8 ft arrange bracing as shown in dotted lines
For heights from 20 ft. to 32 ft (drawn for 26'-0")
Batter 1" per ft
$\frac{3}{4}$" Bolt
2-$\frac{3}{8}$"×8"
Boat
Spikes
2-3"×10"
1"×10" Dowel

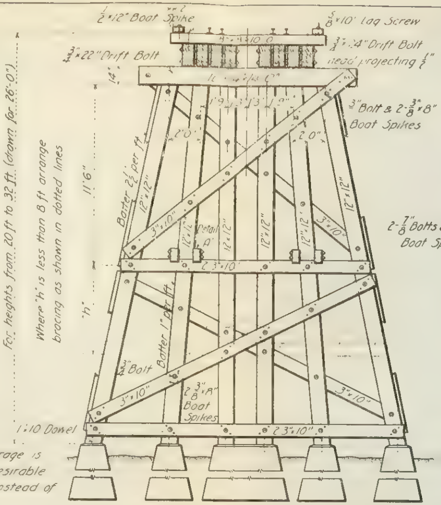
Where anchorage is considered desirable use straps instead of dowels

Typical 5 Post Bent 20 ft. to 32 ft

12 & 14 ft Panel Lengths

Foundation either piles or concrete

Continuous foundations may be used when local conditions justify



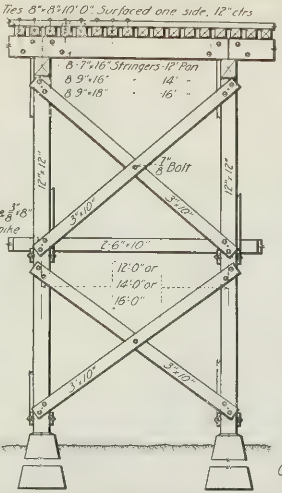
$\frac{1}{2}$"×12" Boat Spike
$\frac{5}{8}$"×10" Lag Screw
$\frac{3}{4}$"×22" Drift Bolt
$\frac{3}{4}$"×24" Drift Bolt
Head projecting $\frac{1}{2}$"
14"×14"×16'-0"
1'-9" 3'-3" 1'-9"
$\frac{3}{4}$" Bolt & 2-$\frac{3}{8}$"×8"
Boat Spikes
2'-0"
2'-0"
For heights from 20 ft. to 32 ft. (drawn for 26'-0")
Where "h" is less than 8 ft arrange bracing as shown in dotted lines
11'-6"
"h"
Batter 2$\frac{1}{2}$" per ft
12"×12"
3"×10"
Detail "A"
2-3"×10"
Batter 1" per ft
$\frac{3}{4}$" Bolt
2-$\frac{3}{8}$"×8"
Boat
Spikes
1"×10" Dowel

Typical 6 Post Bent 20 ft. to 32 ft.

16 ft Panel Lengths

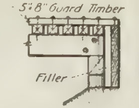
Foundation either piles or concrete

Sway bracing on 6 post bents up to 19 ft to be similar to bracing on 5 post bents up to 19 ft

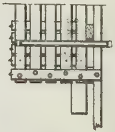


Ties 8"×8"×10'-0". Surfaced one side, 12" ctrs
8-7"×16" Stringers-12' Pan
8-9"×16" " 14' "
8-9"×18" " 16' "
12"×12"
$\frac{7}{8}$" Bolt
3"×10"
2-$\frac{7}{8}$" Bolts & $\frac{3}{8}$"×8" Boat Spike
2-6"×10"
12'-0" or
14'-0" or
16'-0"

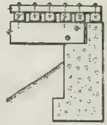
Elevation



Timber Bulkhead



Plan



Concrete Bulkhead

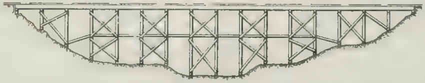
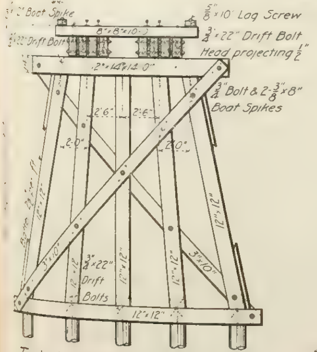


Diagram Showing Longitudinal Bracing

Frame trestles to have longitudinal bracing for all heights

PERMISSIBLE WORKING STRESSES	DENSE PINE	DOUGLAS FIR
Extreme Fibre stress in bending	1400# per □"	1400# per □"
Compression across grain	250# " □"	250# " □"
Longitudinal Shear	125# " □"	100# " □"
Load on piles (D+L)	15 Tons	

Stresses to be used without adding anything to live load for impact

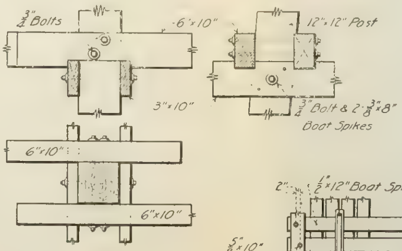


$\frac{1}{2}$"×12" Boat Spike
$\frac{3}{4}$"×22" Drift Bolt
8"×8"×10'-0"
$\frac{5}{8}$"×10" Lag Screw
$\frac{3}{4}$"×22" Drift Bolt
Head projecting $\frac{1}{2}$"
2-14"×14"-14'-0"
$\frac{3}{4}$" Bolt & 2-$\frac{3}{8}$"×8"
Boat Spikes
2'-6"
2'-6"
2'-0"
2'-0"
Batter 2$\frac{1}{2}$" per ft
12"×12"
3"×10"
$\frac{3}{4}$"×22"
Drift
Bolts
12"×12"

Typical 5 Post Bent Up to 19 ft.

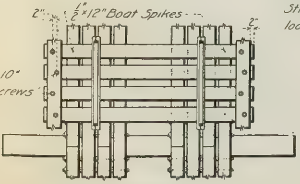
12 & 14 ft Panel Lengths

Foundation either piles or concrete



Detail at "A"

Note
Dimensions of timbers are nominal sizes
Super-elevation for curves to be framed in posts



Plan

RECOMMENDED PRACTICE
for
OPEN DECK FRAME TRESTLE
HEAVY DESIGN E 60 LOADING
A. R. E. A.

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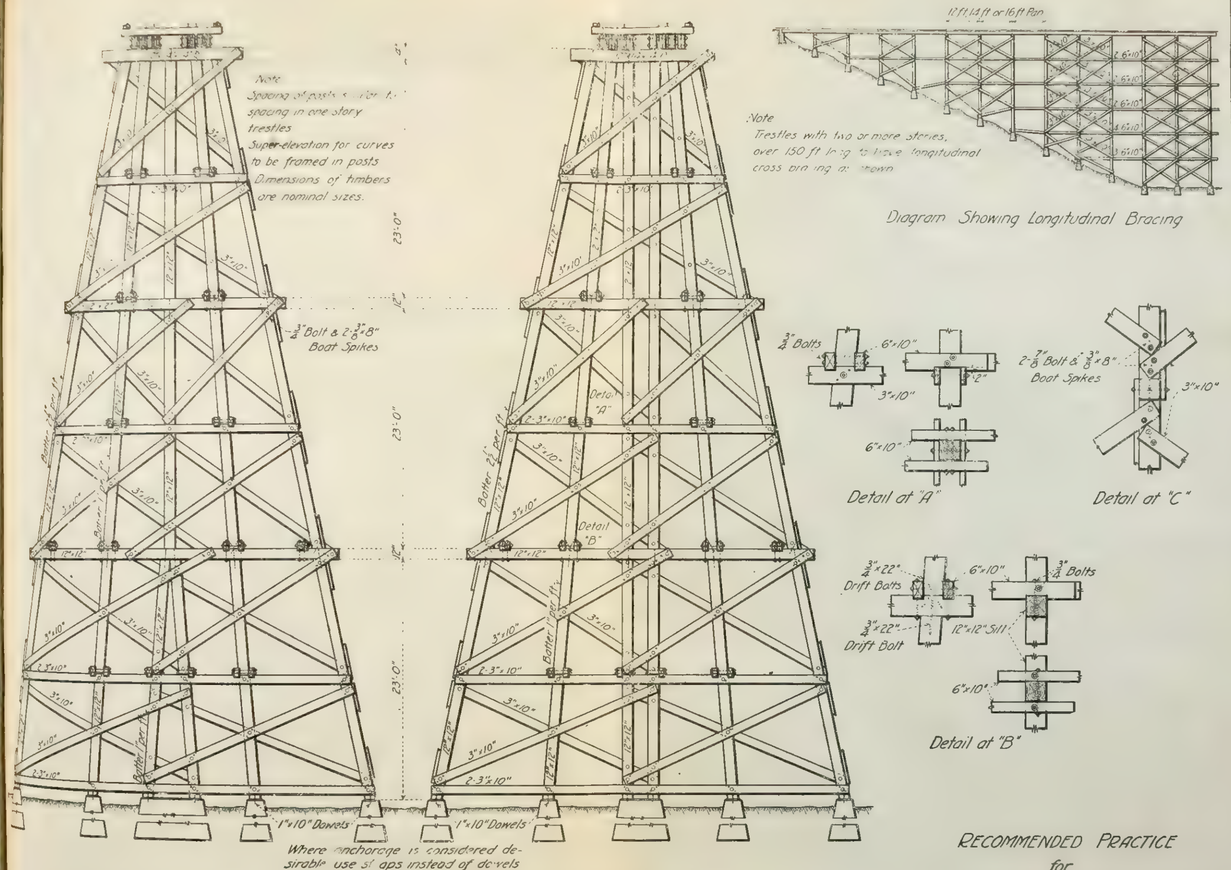

Note
Spacing of posts similar to spacing in one story trestles
Super-elevation for curves to be framed in posts
Dimensions of timbers are nominal sizes.

Note
Trestles with two or more stories, over 150 ft long to have longitudinal cross bracing as shown

Diagram Showing Longitudinal Bracing

Detail at "A"

Detail at "C"

Detail at "B"

Where anchorage is considered desirable use straps instead of dowels

Typical 5 Post Bent
12 ft & 14 ft Panel Lengths

Typical 6 Post Bent
16 ft Panel Lengths

Note: Continuous foundations may be used when local conditions justify

RECOMMENDED PRACTICE
for
MULTIPLE STORY TRESTLES
HEAVY DESIGN E60 LOADING
A. R. E. A.

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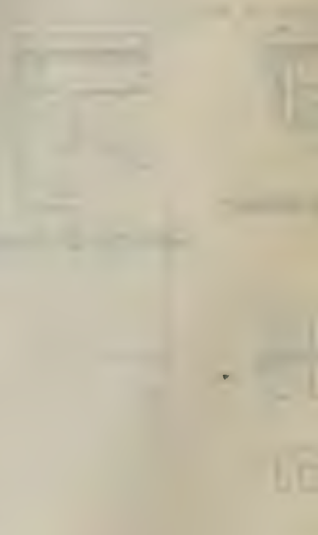

[illegible]

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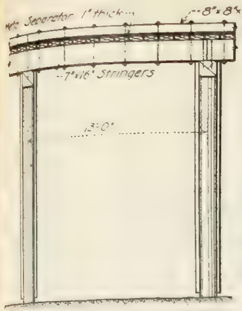
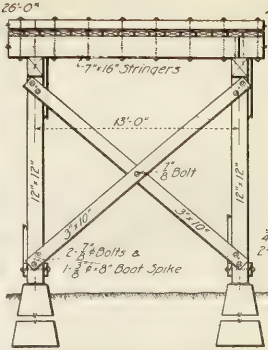
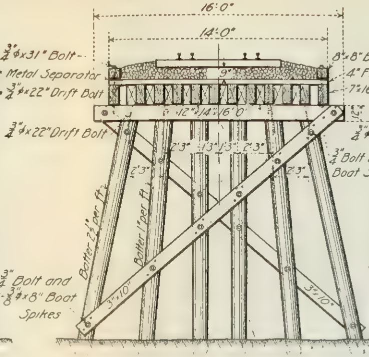


Elevation - Typical Pile Bent

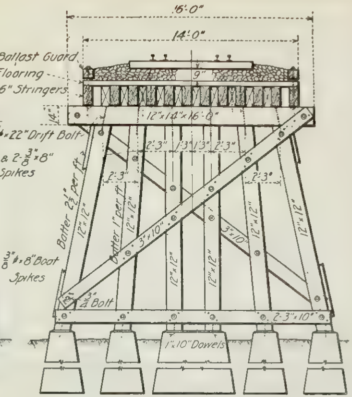


Elevation - Typical Frame Bent

Where anchorage is considered desirable use straps instead of dowels

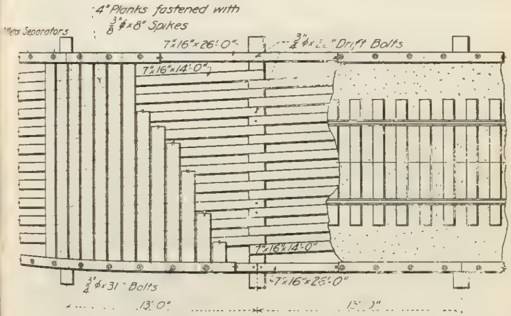


Typical Pile Bent

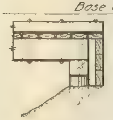


Typical Frame Bent

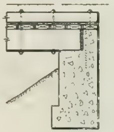
Continuous concrete foundations may be used when local conditions justify



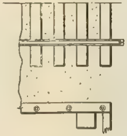
Plan



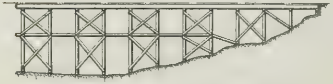
Timber Bulkhead



Concrete Bulkhead

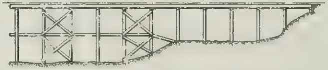


Plan



Longitudinal Bracing on Frame Trestles

Frame trestles to have longi bracing for all heights.



Longitudinal Bracing on Pile Trestles

Pile trestles which are 100 ft or more in length, and over 15 ft in height from Base of Rail to ground shall have longitudinal cross bracing every 2nd or 3rd Panel. Longitudinal girts must be carried to bank, and securely fastened to bent near ground line.

PERMISSIBLE WORKING STRESSES	DENSE PINE	DOUGLAS FIR
Extreme fibre stress in bending	1400# per □"	1400# per □"
Compression across grain	250# " □"	250# " □"
Longitudinal Shear	125# " □"	100# " □"
Load on piles (D+L)	15 Tons	

Stresses to be used without adding anything to live load for impact

Note
Dimensions of timbers are nominal sizes

RECOMMENDED PRACTICE
for
BALLAST DECK TIMBER TRESTLES
HEAVY DESIGN - E 60 LOADING
A.R.E.A.

(10) There is danger from overdriving when the hammer begins to bounce. Overdriving is also indicated by the bending, kicking or staggering of the pile.

(11) The brooming of the head of the pile dissipates a part, and in some cases all, of the energy due to the fall of the hammer.

(12) The steam hammer is usually more effective than the drop hammer in securing the penetration of a wooden pile without injury, because of the shorter interval between blows.

(13) Where shock to surrounding material is apt to prove detrimental to the structure, the steam hammer should always be used instead of the drop hammer. This is especially true in the case of sheet piling which is intended to prevent the passage of water. In some cases also the jet should not be used.

(14) In general, the resistance of piles, penetrating soft material, depending solely upon skin friction, is materially increased after a period of rest. This period may be as short as fifteen minutes, and rarely exceeds twelve hours.

(15) Where a pile penetrates a soft yielding material and bears upon hard stratum at its foot, its strength should be determined as a column; omitting the resistance, if any, due to skin friction.

(16) Unless the record of previous experience at the same site is available, the approximate bearing power may be obtained by loading test piles. The results of loading test piles should be used with caution, unless their condition is fairly comparable with that of the piles in the proposed foundation.

(17) In case the piles in a foundation are expected to act as columns, the results of loading test piles should not be depended upon unless they are sufficient in number to insure their action in a similar manner; and unless they are stayed against lateral motion.

(18) Before testing the penetration of a pile in soft material where its bearing power depends principally, or wholly, upon skin friction, the pile should be allowed to rest for 24 hours after driving.

(19) Where the resistance of piles depends mainly upon skin friction it is possible to diminish the combined strength, or bearing capacity, of a group of piles by driving additional piles within the same area.

(20) Where piles will foot in a hard stratum, investigation should be made to determine that this stratum is of sufficient depth and strength to carry the load.

(21) Timber piles may be advantageously pointed, in some cases to a 4-inch or 6-inch square at the end.

(22) Piles should not be pointed when driven into soft material.

(23) Shoes should be provided for piles when the driving is very hard, especially in riprap or shale. These shoes should be so constructed as to form an integral part of the pile.

(24) The use of a cap is advantageous in distributing the impact of the hammer more uniformly over the head of the pile, as well as in holding it in position during driving.

[12]PILE RECORD FORM

Size 8½x11 or 8x10½ inches. Form M.W. 701.

North and South Railroad

Pile Record of Bridge..

LOCATION...

Weight and Kind of Hammer..............................**Date**..............**19**....

Bents Numbered from North or East End **Piles numbered from Left to Right**

Date	Bent No.	No. of Pile	Size of Pile			Kind of Wood	Cut-off	Base-rail to Ground	Total Penetrat.	Av. Last Five Blows		Kind of Soil	Remarks
			Tip End	Butt End	Length					Drop of Ham'r	Penetrat.		

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[12] Adopted, Vol. 12, Part 1, 1911, pp. 278, 307.

[13]SPECIFICATIONS FOR WORKMANSHIP FOR PILE AND FRAME TRESTLES OF UNTREATED MATERIAL TO BE BUILT UNDER CONTRACT

Site

1. The trestle to be built under these specifications is located on the line of .... Railway at ....
County of .... State of ....

General Description

2. The work to be done under these specifications covers the construction of a ....track wooden trestle about .... feet long and an average of .... feet high.

General Clauses

3. The Contractor shall furnish all necessary labor, tools, machinery, supplies, temporary staging and outfit required. He shall build the complete trestle ready for the track rails, in a workmanlike manner, in strict accordance with the plans and the true intent of these specifications, to the satisfaction and acceptance of the Engineer of the Railway Company.

4. The workmanship shall be of the best quality in each class of work. Details, fastenings and connections shall be of the best method of construction in general use on first-class work.

5. Holes shall be bored for all bolts. The depth of the hole and the diameter of the auger shall be as specified by the Engineer.

6. Framing shall be accurately fitted. No blocking or shimming will be allowed in making joints. Timbers shall be cut off with the saw; no axe to be used.

7. Joints and points of bearing, for which no fastening is shown on the plans, shall be fastened as specified by the Engineer.

Detail Specifications

8. Piles shall be carefully selected to suit the place and ground where they are to be driven. When required by the Engineer, pile butts shall be banded with iron or steel for driving, and the tips shod with suitable iron or steel shoes. Such shoes will be furnished by the Railway Company.

9. Piles shall be driven to firm bearing, satisfactory to the Engineer; or until five blows of a hammer weighing 3000 lb., falling 15 feet (or a hammer and fall producing the same mechanical effect), are required to cause an average penetration of ½ inch per blow, except in soft bottom, where special instructions will be given.

10. Batter piles shall be driven to the inclination shown by the plans, and shall require but slight bending before framing.

11. Butts of all piles in a bent shall be sawed off to one plane and trimmed so as not to leave any horizontal projection outside of the cap.

12. Piles injured in driving, or driven out of place, shall either be pulled out or cut off, and replaced by new piles.

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[13] Adopted, Vol. 8, 1907, pp. 397-400, 442-450.

Caps

13. Caps shall be sized and brought to a uniform thickness and even bearing on piles or posts. The side with most sap shall be placed downward.

Posts

14. Posts shall be sawed to proper length for their position (vertical or batter), and to even bearing on cap and sill.

Sills

15. Sills shall be sized at the bearing of posts to one plane.

Sash and Sway Braces

16. Sash and sway bracing shall be properly framed and securely fastened to piles or posts. When necessary, filling pieces shall be used between the braces and the piles of a bent on account of the variation in size of piles, and securely fastened and faced to obtain a bearing against all piles.

Longitudinal Braces

17. Longitudinal X braces shall be properly framed and securely fastened to piles or posts.

Girts

18. Girts shall be properly framed and securely fastened to caps, sub-sills, intermediate sills, posts or piles, as the plans may require.

Stringers

19. Stringers shall be sized to a uniform depth at supports. The edges with most sap shall be placed downward.

Jack Stringers

20. Jack stringers, if required on the plans, shall be neatly framed on caps, and their tops shall be in the same plane as the track stringers.

Ties

21. Ties shall be sized to a uniform thickness and shall be placed with the rough side upward. They shall be spaced regularly and cut to even length and line, as called for on the plans.

Guard Timbers

22. Guard timbers shall be framed as called for on the plans, laid to line and to a uniform top surface. They shall be firmly fastened to the ties as required.

Bulkheads

23. Bulkheads shall be of sufficient dimensions to keep the embankment clear of the caps, stringers and ties, at the end bents of the trestle. There shall be a space of not less than 2 inches between the back of the end bent and the face of the bulkhead. The projecting ends of the bulkhead shall be sawed off to conform to the slope of the embankment, unless otherwise specified.

[14]SPECIFICATIONS FOR METAL DETAILS USED IN WOODEN BRIDGES AND TRESTLES

Wrought-Iron

1. Wrought-iron shall be double-rolled, tough, fibrous and uniform in character. It shall be thoroughly welded in rolling and be free from surface defects. When tested in specimens of the form of Fig. 1 or in full-sized pieces of the same length, it shall show an ultimate strength of at least 50,000 lb. per square inch, an elongation of 18 per cent in 8 in., with fracture wholly fibrous. Specimens shall bend cold, with the fiber, through 135 degrees, without sign of fracture, around a pin the diameter of which is not over twice the thickness of the piece tested. When nicked and bent, the fracture shall show at least 90 per cent fibrous.

Steel

2. Steel shall be made by the open-hearth process and shall be of uniform quality. It shall contain not more than 0.05 per cent sulphur. If made by the acid process it shall contain not more than 0.06 per cent phosphorus; and if made by the basic process, not more than 0.04 per cent phosphorus.

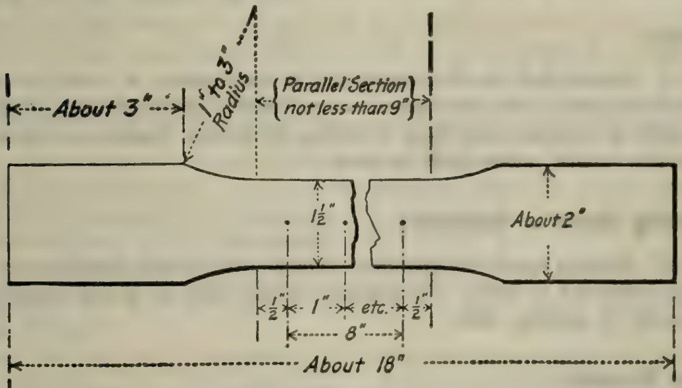

FIG. 1

When tested in specimens of the form of Fig. 1, or full sized pieces of the same length, it shall have a desired ultimate tensile strength of 60,000 lb. per square inch. If the ultimate strength varies more than 4000 lb. from that desired, a retest shall be made on the same gage, which, to be acceptable, shall be within 5000 lb. of the desired ultimate. It shall have a minimum percentage of elongation in 8 inches of $\frac{1,500,000}{\text{ultimate tensile strength}}$; and shall bend cold without fracture 180 degrees flat. The fracture for tensile tests shall be silky.

Cast-Iron

3. Except where chilled iron is specified, castings shall be made of tough grey iron, with sulphur not over 0.10 per cent. They shall be true

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[14] Adopted, Vol. 7, 1906, pp. 692-694, 719-724; Vol. 11, 1910.

to pattern, out of wind and free from flaws and excessive shrinkage. If tests are demanded, they shall be made on the "Arbitration Bar" of the American Society for Testing Materials, which is a round bar 1¼ inches in diameter and 15 inches long. The transverse test shall be made on a supported length of 12 inches, with load at middle. The minimum breaking load so applied shall be 2900 lb., with a deflection of at least 1/10 inch before rupture.

Bolts

4. Bolts shall be of wrought-iron or steel, made with square heads, standard size, the length of thread to be 2½ times the diameter of bolt. The nuts shall be made square, standard size, with thread fitting closely the thread of bolt. Threads shall be cut according to U.S. standards.

Drift Bolts

5. Drift bolts shall be of wrought-iron or steel, with or without square head, pointed or without point, as may be called for on plans.

Spikes

6. Spikes shall be of wrought-iron or steel, square or round, as called for on the plans. Steel wire spikes, when used for spiking planking, shall not be used in lengths more than 6 inches; if greater lengths are required, wrought or steel spikes shall be used.

Packing Spools or Separators

7. Packing spools or separators shall be of cast-iron, made to size and shape called for on plans. The diameter of hole shall be ⅛ inch larger than diameter of packing bolts.

Cast Washers

8. Cast washers shall be of cast-iron. The diameter shall be not less than 3½ times the diameter of bolt for which it is used, and its thickness equal to the diameter of bolt. The diameter of hole shall be ⅛ inch larger than the diameter of the bolt.

Wrought Washers

9. Wrought washers shall be of wrought-iron or steel, the diameter shall be not less than 3½ times the diameter of bolt for which it is used, and not less than ¼ inch thick. The hole shall be ⅛ inch larger than the diameter of the bolt.

Special Castings

10. Special castings shall be made true to pattern, without wind, free from flaws and excessive shrinkage; size and shape to be as called for by the plans.

[15]SPECIFICATIONS FOR TIMBER PILES

Kinds of Wood

1. The railway will specify the kind or kinds of wood[a] it desires to use, and will designate the kinds it desires for preservative treatment.

2. Piles of different kinds of wood must be delivered in separate lots.

PHYSICAL REQUIREMENTS

General Quality

3. Except as hereinafter provided, all piles shall be free from any defects which may impair their strength or durability as piling, such as decay, red heart, splits in piles to be treated, or splits longer than measured butt diameter of piles not to be treated, twist of grain exceeding one-half of the circumference in any twenty feet of length, unsound knots, numerous knots or holes, or shake more than one-third of the diameter of pile. Sound knots will be permitted, provided they are not in clusters. The maximum diameter of a sound knot shall not exceed one-third of the least diameter of the section where it occurs, and shall not exceed four inches. A sound knot shall be one which at a depth not greater than its diameter shows wood as hard as that surrounding the knot.

4. All piles shall be cut from sound, live trees, except that fire or blight-killed, or wind-felled timber may be used if not attacked by decay or insects.

5. The tip must be sound.

6. The butt end must be sound in all except cedar piles, which may have a pipe or stump rot hole not more than 1½ inches in diameter.

7. The diameter of a pile in cases where the tree is not exactly round, should be ascertained by measuring the circumference and dividing the number of inches in it by the number, 3.14.[b]

8. Piles shall taper uniformly from the point of butt measurement to the tip.

Close Grain

9. If close grain is specified for softwood piles, they shall show on the butt end not less than six annual rings per inch, measured radially over the outer three inches of the cross-section. Douglas fir and Southern pine averaging from five to six annual rings per inch shall be accepted as the equivalent of close grain if having one-third or more summerwood.

Resistance to Decay

10. Piles for use without preservative treatment shall have as little sapwood as possible.

11. Piles for use with preservative treatment shall have no sapwood restrictions, but have, preferably, as much sapwood as possible; in Southern pine a thickness of not less than 1½ inches and in Douglas fir of not less than one inch of the butt end. Care shall be taken to remove as little sapwood as possible while peeling bark. The sapwood shall not be injured by unnecessary axe cuts. These piles shall be designated as sap piles.

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[a] The most commonly used species are cedars, cypress, Douglas fir, oaks, pines and spruces.

[b] This diameter may be determined by using a steel tape suitably marked to give the diameter by measuring the circumference.

[15]Adopted, Vol. 10, 1909, pp. 541, 609; Vol. 29, 1928, pp. 506, 1302.

DESIGN

Dimensions—First-Class Piles

12. Southern pine and Douglas fir piles shall have the following limiting dimensions:

Length	*Diameter 3 ft. from Butt* *Min.*	*Max.*	*Diameter of Tip* *Min.*
Under 40 ft.	14 in.	18 in.	10 in.
40 ft. to 50 ft.	14 in.	18 in.	9 in.
50 ft. to 70 ft.	14 in.	18 in.	8 in.
70 ft. to 90 ft.	14 in.	18 in.	7 in.
Over 90 ft.	14 in.	20 in.	6 in.

13. Red oak, willow oak, black oak, white oak, pin oak, post or burr oak, or cypress piles shall have the following limiting dimensions:

Length	*Diameter 6 ft. from Butt* *Min.*	*Max.*	*Diameter of Tip* *Min.*
Under 30 ft.	12 in.	18 in.	10 in.
30 ft. to 40 ft.	12 in.	18 in.	9 in.
Over 40 ft.	12 in.	18 in.	8 in.

14. Western red cedar piles shall have the following limiting dimensions:

Length	*Diameter 6 ft. from Butt* *Min.*	*Max. Widest Part*	*Diameter of Tip* *Min. any Point*
30 ft. or less	14 in.	22 in.	10 in.
30 ft. to 40 ft.	14 in.	22 in.	9 in.
Over 40 ft.	14 in.	22 in.	8 in.

Dimensions—Second-Class Piles

15. Piles for foundations that will always be completely submerged, and piles for coffer-dams, falsework and sundry temporary work may be of sound, live timber that will stand driving, and need not be peeled. They shall be free from bad knots, decayed timber, shakes and other imperfections which will seriously affect their strength. They shall be of the following general dimensions: :

Length	*Diameter 3 ft. from Butt* *Min.*	*Max.*	*Diameter of Tip* *Min.*
40 ft. or less	12 in.	18 in.	8 in.
Over 40 ft.	12 in.	18 in.	6 in.

Tolerance

16. Dimensions given are minimum or maximum as stated, but a tolerance of ½ inch less in a given diameter will be allowed in not more than 25 per cent of the pieces of that diameter.

Length

17. All piles shall be furnished on order cut to any of the following lengths: 16 feet to 40 feet in multiples of two feet and over 40 feet in multiples of 5 feet. A variation of six inches in length is allowable, but the average length in any shipment must be equal to, or greater than, the billed length.

Straightness

18. Piles shall be free from short or reversed bends, and free from crooks greater than one-half the diameter of the pile at the middle of the

bend. A line drawn from the center of the butt to the center of the tip shall lie within the body of the pile.

MANUFACTURE

19. All knots and limbs shall be trimmed or smoothly cut flush with the surface of the pile. Ends must be cut square with axis of pile.

20. When specified, piles must be peeled of bark including the inner skin soon after cutting so that the piles are smooth and clean.

INSPECTION

Place

21. Piles will be inspected at suitable and convenient places satisfactory to the railway, at points of shipment or at destination. Piles will be inspected at points other than the railway's property whenever in the judgment of the railway there is sufficient number to warrant it; but the shipper shall provide accommodations for the inspector at the expense of the railway, while away from rail or steamer lines, and shall transport him from and to a railway station or steamer landing.

Manner

22. Inspectors will make a thorough examination of each pile. Each pile shall be judged independently without regard for the decisions on others in the same lot. Piles too muddied for ready examination will be rejected. Piles will be turned over as inspected, at the expense of the producer.

Manufacture

23. Piles shall be inspected for workmanship and conformity with these specifications in all respects.

DELIVERY

24. Piles delivered on the premises of a railway for inspection shall be stacked not less than 10 feet from the nearest rail of any track, or from highways, at suitable and convenient places, but not at public crossings, nor where they will interfere with the view of trainmen or of people approaching the railway. Piles shall be stacked in a secure manner in order that they shall not roll onto the railroad tracks or highway.

25. Each stack shall have fastened to it a tag on which is written the owner's name and address, the date when stacked, and the number of piles of each kind of wood in the stack. Piles for use without preservative treatment and those for preservative treatment shall be stacked separately.

26. All piles are at the owner's risk until accepted. All rejected piles shall be removed within one month after inspection, if required by the railway.

SHIPMENT

27. Piles forwarded in cars or vessels shall be separated therein according to the kinds, sizes and lengths if inspected before loading, or as may be stipulated in the contract or order for them.

[16]GRADING RULES AND CLASSIFICATION OF TIMBER AND LUMBER FOR RAILWAY USES

COMMERCIAL NAMES FOR LUMBER AND TIMBER CUT FROM THE PRINCIPAL SPECIES OF SOFTWOODS

The following standard commercial names for lumber and timber cut from species of softwood as listed under botanical names shall be used in the construction of contracts and other documents arising in transactions of purchase and sale of American Standard Lumber. Preferred commercial names are underscored.

Commercial Name	*Botanical Name*
	Cedars and Junipers
Alaska Cedar	Chamæcyparis nootkatensis
Eastern Red Cedar	Juniperus virginiana, Juniperus lucayana (southern red cedar) and Juniperus Mexicana (mountain juniper)
Incense Cedar	Libocedrus decurrens
Northern White Cedar	Thuja occidentalis
Port Orford Cedar	Chamæcyparis lawsoniana
Southern White Cedar	Chamæcyparis thyoides
Western Juniper	Juniperus utahensis (Utah juniper), Juniperus pachyphloea (alligator juniper), Juniperus scopulorum (Rock Mt. red cedar), and Juniperus occidentalis (western juniper)
Western Red Cedar	Thuja plicata
	Cypress
Red Cypress	Taxodium distichum (Coast type)
Yellow Cypress	Taxodium distichum (Inland type)
White Cypress	Taxodium distichum (Inland type)
	Douglas Fir
Douglas Fir	Pseudotsuga taxifolia (Coast type)
Red Fir	Pseudotsuga taxifolia (Intermountain type)
Red Fir	Pseudotsuga taxifolia (Rocky Mountain type)
	The True Firs
Alpine Fir	Abies lasiocarpa
Balsam Fir	Abies balsamea and Abies fraseri (Southern balsam fir)

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[16] Adopted, Vol. 22, 1921, pp. 494, 1072; Vol. 27, 1926, pp. 833, 1408; Vol. 28, 1927, pp. 323, 1425; Vol. 30, 1929, pp. 1147, 1456.

Commercial Name	*Botanical Name*
Golden Fir	Abies magnifica
Noble Fir	Abies nobilis
Silver Fir	Abies amabilis
White Fir	Abies concolor and Abies grandis (lowland white fir)
Hemlocks	
Eastern Hemlock	Tsuga canadensis and Tsuga Caraliniana (Carolina hemlock)
Mountain Hemlock	Tsuga mertensiana
West Coast Hemlock	Tsuga heterophylla
Larch	
Western Larch	Larix occidentalis
Pines	
Arkansas Soft Pine	Pinus echinata and taeda
California White Pine	Pinus ponderosa and Pinus jeffreyi (Jeffrey pine)
Idaho White Pine	Pinus monticola
Jack Pine	Pinus banksiana
Loblolly Pine	Pinus taeda
Lodgepole Pine	Pinus contorta
Longleaf Pine	Pinus palustris
North Carolina Pine	Pinus taeda and echinata, and Pinus Virginiana (Virginia Pine)
Northern White Pine	Pinus strobus
Norway Pine	Pinus resinosa
Pond Pine	Pinus rigida serotina
Pondosa Pine	Pinus ponderosa
Shortleaf Pine	Pinus echinata
Slash Pine	Pinus caribaea
Southern Pine	Pinus taeda, palustris, serotina, echinata, and caribaea, and Pinus rigida (pitch pine) and Pinus glabra (spruce pine)
Sugar Pine	Pinus lambertiana
Redwood	
Redwood	Sequoia sempervirens
Spruces	
Eastern Spruce	Picea mariana (black spruce), Picea rubra (red spruce), and Picea glauca (white spruce)
Engelmann Spruce	Picea engelmanni and Picea parryana (blue spruce)
Sitka Spruce	Picea sitchensis

Commercial Name	*Botanical Name*
	Tamarack
TAMARACK	Larix laricina
	Yew
PACIFIC YEW	Taxus brevifolia

USE CLASSIFICATION

Lumber is the product of the saw and planing mill not further manufactured than by sawing, resawing, and passing lengthwise through a standard planing machine, crosscut to length, and matched.

Lumber is classified as (a) yard lumber, (b) structural timbers, and (c) shop or factory lumber. Different grading rules apply to each class of lumber.

Yard lumber is lumber that is less than five (5) inches in thickness and is intended for general building purposes. The grading of yard lumber is based upon the use of the entire piece.

Structural timber is lumber that is five (5) inches or over in thickness and width. The grading of structural timbers is based upon the strength of the piece and the use of the entire piece.

Shop or factory lumber is lumber intended to be cut up for use in further manufacture. It is graded on the basis of the percentage of the area which will produce a limited number of cuttings of a given minimum size and quality.

SIZE CLASSIFICATION

Yard Lumber

Strips are yard lumber less than two (2) inches thick and under eight (8) inches wide.

Boards are yard lumber less than two (2) inches thick, eight (8) inches or over in width.

Dimension includes all yard lumber except boards, strips and timbers, that is, yard lumber two (2) inches and under five (5) inches thick, and of any width.

Planks are dimension lumber two (2) inches and under four (4) inches thick and eight (8) inches and over wide.

Scantlings are dimension lumber two (2) inches and under five (5) inches thick and under eight (8) inches wide.

Heavy joists are dimension lumber (4) inches thick and eight (8) inches or over wide.

Structural timbers are lumber five (5) inches or larger in least dimension.

MANUFACTURING CLASSIFICATION

Manufactured lumber is classified as rough, surfaced, and worked.

Rough lumber is undressed lumber as it comes from the saw.

Surfaced lumber is lumber that is dressed by running through a planer. It may be surfaced on one side (S1S), two sides (S2S), one edge (S1E), two edges (S2E), or a combination of sides and edges (S1S1E) (S2S1E) (S-S2E) or (S4S).

Worked lumber is lumber which has been run through a matching machine, sticker or molder. Worked lumber may be matched, shiplapped or patterned.

Matched lumber is lumber that is edge dressed and shaped to make a close tongue and groove joint at the edges or ends when laid edge to edge or end to end.

Shiplapped lumber is lumber that is edge dressed to make a close rabbetted or lapped joint when laid edge to edge.

Patterned lumber is worked lumber that is shaped to a patterned or moulded form.

DEFINITIONS OF MAXIMUM DEFECTS AND BLEMISHES

The following definitions vary slightly from the definitions of the American Lumber Standards. Definitions of regional lumber associations also vary slightly from American Lumber Standards. This should be considered in making contracts.

The terms "Defect" and "Blemish" as applied to wood usually imply the idea of imperfections. These are not always detrimental.

DEFECT.—Any irregularity or want occurring in or on wood that may lower some of its strength, durability or utility values.

BLEMISH.—Any mark or formation of wood structure, not classified as a defect, marring the appearance of the wood.

The presence of a defect or blemish may or may not be detrimental to the value of the material, depending upon the character of the defect or blemish and the use of the material.

Bark Pocket

BARK POCKET.—A patch of bark partially or wholly enclosed in the wood. In size it is classified the same as pitch pockets.

Bird's-Eye

"BIRD'S-EYE."—A small central spot with the wood fibers arranged around it in the form of an ellipse, so as to give the appearance of an eye. "Bird's-Eye," unless unsound or hollow, shall not be considered a defect.

Checks

CHECK.—A lengthwise separation of the wood, which occurs usually across the rings of annual growth.

SURFACE CHECK.—A check occurring on the surface of the piece.

SMALL SURFACE CHECK.—A perceptible opening not over four (4) inches long.

MEDIUM SURFACE CHECK.—A check not over $\frac{1}{32}$ inch wide and over four (4) but not more than ten (10) inches long.

LARGE SURFACE CHECK.—A check over $\frac{1}{32}$ inch wide and over ten (10) inches long.

End Check.—Check occurring on an end of a piece.

Through Check.—Check extending from one surface through the piece to the opposite surface or to an adjoining surface.

Heart Check.—Check starting at the pith and extending toward but not to the surface of a piece.

Honeycombing.—Checks occurring in the interior of a piece, often not visible on the surface. On a cross-section they usually appear as slits, or as open pockets whose width may appear very large in proportion to the radial length.

Cross Breaks

Cross Break.—A separation of the wood cells across the grain, such as may be due to tension resulting from unequal shrinkage or mechanical stresses.

Cross Grain

Cross Grain.—Wood in which the cells or fibers do not run parallel with the axis, or sides, of a piece. It may be classified as spiral, diagonal, wavy, dip, curly and interlocked grain. The slope of the grain can be determined by observing the direction of surface checks, resin ducts, pores of the wood, annual layers of growth, etc. A drop of stained liquid, such as ink, tends to elongate in the direction of the grain when placed on a smooth surface of the piece.

Spiral Grain.—Wood in which the fibers take a more or less winding or spiral course, such as occurs in a twisted tree. It may be detected on the flat grain (plain sawed or tangential) surface.

Diagonal Grain.—Wood in which the fibers extend at an angle (i. e., diagonally) across a piece as a result of sawing at an angle across the annual layers of growth. It may appear on either the radial or tangential surface.

Wavy Grain.—Wood in which the fibers take the form of waves or undulations as indicated by the wavy surface of the split piece. It may appear on either the radial or tangential surfaces.

Dip Grain.—Wood which has one wave or undulation of the fibers such as occurs around knots, pitch pockets, etc.

Curly Grain.—Wood in which the fibers are distorted so that they take a curled direction as in "Bird's-Eye Wood." These patches may vary up to several inches in diameter.

Interlocked Grain.—Wood which shows spiral grain in one direction for a number of years and then the slope of the grain in the succeeding annual layers of growth turns in a reverse direction around the tree, then later reverses back, etc.

Slight Cross Grain.—Wood in which slope of the grain is not over one (1) inch in a length of fifteen (15) inches.

Medium Cross Grain.—Wood in which slope of the grain is over one (1) inch in a length of fifteen (15) inches but not more than one (1) inch in a length of ten (10) inches.

Steep Cross Grain.—Wood in which slope of the grain is over 1 inch in a length of 10 inches.

Decay

DECAY.—A disintegration of wood substance due to the action of wood-destroying fungi. The words "dote" and "rot" mean the same as decay.

INCIPIENT DECAY.—An early stage of decay in which the disintegration has not proceeded far enough to soften or otherwise change the hardness of the wood perceptibly. It is usually accompanied by a slight discoloration or bleaching of the wood.

FIRM RED HEART.—A stage of incipient decay characterized by a reddish color produced in the heartwood, which does not unfit the wood for the majority of yard purposes.

WATER-SOAK (OR STAIN).—A term applied to a generally water-soaked area in heartwood, which is usually interpreted as the incipient stage of certain wood rots.

ADVANCED (OR TYPICAL) DECAY.—The older stage of decay in which the disintegration is readily recognized because the wood has become punky, soft and spongy, stringy, ringshaked, pitted or crumbly. Decided discoloration or bleaching of the rotted wood is often apparent.

POCKET ROT.—Typical decay which appears in the form of a hole, pocket, or area of soft rot, usually surrounded by apparently sound wood.

SOUND WOOD.—Wood free from any form of decay, incipient or advanced, including firm red heart, dote and rot.

Gum Spots and Streaks

GUM SPOT OR STREAK.—An accumulation of gum-like substance occurring as a small patch or streak in a piece. They may occur in conjunction with a bird peck, or other injury to the growing wood. In size they are classified the same as pitch pockets or pitch streaks.

Holes

Holes in wood may extend partially or entirely through the piece and be from any cause.

When holes are permitted, the average of the maximum and minimum diameter measured at right angles to the direction of the hole shall be used in measuring the size, unless otherwise stated.

Pin worm hole—One not over $\frac{1}{16}$ inch in diameter.

Medium worm hole—One over $\frac{1}{16}$ but not more than $\frac{1}{4}$ inch in diameter.

Large worm hole—One over $\frac{1}{4}$ inch in diameter.

Imperfect Manufacture

Imperfect manufacture includes all defects or blemishes which are produced in manufacturing, such as chipped grain, loosened grain, raised grain, torn grain, skips in dressing, hit or miss, variation in sawing, miscut lumber, machine burn, machine gouge, mismatching and insufficient tongue or groove.

CHIPPED GRAIN.—A part of the surface chipped or broken out in very short particles below the line of cut. It should not be classed as torn grain and, as usually found, shall not be considered a defect, unless it is present in excess of 25 per cent of the area.

Loosened Grain.—A small portion of the wood which has become loosened but not displaced. It occurs on the heartside of the piece and is a serious defect, especially in flooring.

Raised Grain.—A roughened condition of the surface of dressed lumber in which the hard summerwood is raised above the softer springwood, but not torn loose from it.

Torn Grain.—A part of the wood which is torn out in dressing, and in depth is of four distinct characters; slight, medium, heavy and deep.

Slight Torn Grain.—Not more than 1/32 inch in depth.

Medium Torn Grain.—More than 1/32 but not more than 1/16 inch in depth.

Heavy Torn Grain.—More than 1/16 but not more than ⅛ inch in depth.

Deep Torn Grain.—More than ⅛ inch in depth.

Skip.—An area on a piece that failed to surface.

Slight Skip.—One that failed to surface smoothly, whose area does not exceed the product of the width of the piece in inches multiplied by six (6).

Heavy Skip.—One that the planer knife did not touch.

Hit or Miss.—A series of skipped spots with surfaced areas between or with skips the entire length when not over 1/16 inch in depth.

Variation in Sawing.—A deviation from the line of cut.

Slight Variation.—Not more than 1/16 inch in one-inch material, ⅛ inch in 2-inch, 3/16 in 3 to 7-inch, and ¼ inch in 8 inches and up.

Miscut Lumber.—That which has a greater variation in thickness or width at different places on the piece than specified for variation in sawing.

Machine Burn.—A darkening or charring of the wood due to overheating by the machine knives.

Machine Gouge.—A groove across a piece due to the machine cutting below the desired line of cut.

Mismatched Material.—Worked material that does not fit tightly at all points of contact between adjoining pieces, or in which the surfaces of adjoining pieces are not in the same plane.

Slight Mismatch.—A surface variation not more than 1/64 inch.

Medium Mismatch.—A surface variation more than 1/64 but not more than 1/32 inch.

Heavy Mismatch.—A surface variation more than 1/32 inch.

Knots

Knot.—A portion of a branch or limb which has become incorporated in the body of the tree. Knots are classified according to size, form, quality and occurrence. They are measured on the surface of the piece. The average of the maximum and minimum diameters shall be used in measuring the size of knots, unless otherwise stated.

Size

Pin Knots.—One not more than ½ inch in diameter.

Small Knot.—One more than ½ inch but not more than ¾ inch in diameter.

Medium Knot.—One more than ¾ inch but not more than 1½ inches in diameter.

Large Knot.—One more than 1½ inches in diameter.

Form

Round Knot.—One oval or circular in form.

Spike Knot.—A branch or limb sawed in a lengthwise direction.

Quality

Sound Knot.—One solid across its face, as hard as the surrounding wood, and showing no indications of decay. It may vary in color from red to black.

Unsound Knot.—One solid across its face but containing incipient decay.

Decayed Knot.—One softer than the surrounding wood and containing advanced decay.

Tight Knot.—One so fixed by growth or position that it will firmly retain its place in the piece.

Intergrown Knot.—One whose rings of annual growth are completely intergrown with those of the surrounding wood.

Watertight Knot.—One whose rings of annual growth are completely intergrown with those of the surrounding wood on one surface of the piece, and which is sound on that surface.

Encased Knot.—One whose rings of annual growth are not intergrown and homogeneous with those of the surrounding wood. The encasement may be partial or complete; or pitch or bark.

Loose Knot.—One not held firmly in place by growth or position and which cannot be relied upon to remain in place in the board.

Pith Knot.—A sound knot with a pith hole not more than ¼ inch in diameter.

Hollow Knot.—An apparently sound knot with a relatively large hole in it.

Occurrence

Single Knot.—One occurring by itself with the fibers of the wood in which it occurs deflected around it.

Knot Cluster.—Two or more knots grouped together as a unit with the fibers of the wood deflected around the entire unit. A group of single knots is not a knot cluster.

Branch Knots.—Two or more knots branching from a common center.

Pitch

Pitch.—A poorly defined accumulation of resin in the wood cells in a more or less irregular patch.

Light Pitch.—Lightly evident presence of pitch.

Medium Pitch.—Slightly more evident trace of pitch than the light pitch.

Heavy Pitch.—Very evident presence of pitch showing by its color and consistency.

Massed Pitch.—A clearly defined accumulation of solid pitch in a body by itself in a piece of lumber.

Pitch Pockets

Pitch Pocket.—A well defined opening between rings of annual growth usually containing, or which has contained, more or less pitch, either solid or liquid. Bark also may be present in the pocket.

Very Small Pitch Pocket.—One not more than ⅛ inch in width and not over two (2) inches in length.

Small Pitch Pocket.—One not more than ⅛ inch in width and not more than 4 inches in length, or not more than ¼ inch in width and not more than 2 inches in length.

Medium Pitch Pocket.—One not more than ⅛ inch in width and not more than 8 inches in length, or not more than ⅜ inch in width and not more than 4 inches in length.

Large Pitch Pocket.—One whose width or length exceeds the maximum stated as permissible for a medium pitch pocket.

Closed Pitch Pocket.—One that does not show an opening on both sides of the piece.

Pitch Seam

Pitch Seam.—A shake or check which is filled with pitch.

Pitch Streaks

Pitch Streak.—A well-defined accumulation of pitch in a more or less regular streak.

Small Pitch Streak.—One not more than 1/12 the width by 1/6 the length of the surface on which it occurs.

Medium Pitch Streak.—One more than 1/12 but not more than 1/6 the width, by over 1/6 but not more than 1/3 the length of the surface on which it occurs.

Large Pitch Streak.—One more than 1/6 the width by 1/3 the length of the surface on which it occurs.

Pith

Pith.—The small soft core occurring in the structural center of the log. The wood immediately surrounding the pith often contains small checks, shake, or numerous pin knots, and is discolored; any such combination of defects and blemishes is known as heart center.

Pith Fleck

Pith Fleck.—A narrow streak resembling pith, usually brownish, up to several inches in length on the surface of a piece resulting from burrowing of larvæ in the growing tissue of the tree.

Shake

Shake.—A lengthwise separation of the wood, which occurs usually between and parallel to the rings of annual growth.

Fine Shake.—One with a barely perceptible opening.

Slight Shake.—One with more than a perceptible opening but not more than 1/32 inch in width.

Medium Shake.—One with an opening more than 1/32 but not more than ⅛ inch width.

Open Shake.—One with an opening more than ⅛ inch wide.

Through Shake.—One extending from one surface through the piece to the opposite surface or to an adjoining surface.

Splits

Split.—A lengthwise separation of the wood, due to the tearing apart of the wood cells.

Short Split.—One whose length does not exceed either the width of a piece or 1/6 its length.

Medium Split.—One whose length exceeds the width of a piece, but does not exceed 1/6 its length.

Long Split.—One whose length exceeds 1/6 the length of a piece.

Stain (or Discoloration)

Stain.—Discoloration, occurring on or in lumber, of any color other than the natural color of the piece on which it appears. It is classified as light, medium and heavy.

Light Stain.—A slight difference in color which will not materially impair the appearance of the piece if given a natural finish.

Medium Stain.—A pronounced difference in color which, although it does not obscure the grain of the wood, would customarily be objectionable in a natural but not in a painted finish.

Heavy Stain.—A difference in color so pronounced as practically to obscure the grain of the wood.

Wane

Wane.—Bark, or lack of wood, from any cause, on the edge or corner of a piece.

Slight Wane.—Not more than ¼ inch wide on the surface on which it appears, for 1/6 the length and ¼ the thickness of the piece.

Medium Wane.—More than ¼ inch but not more than ½ inch wide on the surface on which it appears, for 1/6 the length and ¼ the thickness of the piece.

Large Wane.—More than ½ inch wide on the surface on which it appears, and/or over 1/6 the length and ¼ the thickness of the piece.

Warp

Warp.—Any variation from a true or plane surface. It includes bow, crook, cup, or any combination thereof.

Bow.—Deviation flatwise from a straight line drawn from end to end of a piece, measured at the point of greatest distance from the straight line.

Crook.—Deviation edgewise from a straight line drawn from end to end of a piece, measured at the point of greatest distance from the straight line. It is known as slight, small, medium and large.

Based on a piece 4 inches wide and 16 feet long, the distances for the different degrees of crook shall be for:

Slight crook, a maximum of 1 inch.
Small crook, a maximum of 1½ inches.
Medium crook, a maximum of 3 inches.
Large crook, more than 3 inches.

For wider pieces it shall be ⅛ inch less for each additional 2 inches of width. Shorter or longer pieces may have the same curvature.

Cup.—A curve in a piece across the grain or width of a piece. It is measured at the point of greatest deviation from a straight line drawn from edge to edge of a piece. It is known as slight, medium and deep.

Based on a piece 12 inches wide, the distances for the different degrees of cup shall be for:

Slight cup, a maximum of ¼ inch.
Medium cup, a maximum of ⅜ inch.
Deep cup, a maximum of ½ inch.

Narrower or wider pieces may have the same curvature.

STANDARD LUMBER ABBREVIATIONS

The following standard lumber abbreviations when used in the construction of contracts and other documents arising in transactions of purchase and sale of American standard lumber shall be construed as herein provided:

AD	Air-dried
a. l.	All lengths
av.	Average
av.w.	Average width
av.l.	Average length
a.w.	All widths
B1S	Beaded one side
B2S	Beaded two sides
BBS	Box bark strips
bd.	Board
bd.ft.	Board foot; i. e., an area of one square foot by one inch thick.
bdl.	Bundle
bdl. bk.s.	Bundled bark strips
Bev.	Bevelled
B/L	Bill of Lading
b.m.	Board (foot) measure
Btr.	Better
CB1S&E	Edge and center bead one side; i. e., surfaced one or two sides and with a longitudinal edge and center bead on a surfaced face.
CB2S&E	Edge and center bead two sides; i. e., all four sides surfaced and with a longitudinal edge and center bead on the two faces.
c. & f.	(named port) Cost and freight to named port. Term used when the seller is ready to go farther than the delivery of his goods upon a vessel and is willing to pay transportation to another port.
c.i.f.	(named port) Cost, insurance, and freight to a named port. Term used when the seller desires to quote a price covering the cost of the goods, the marine insurance on the goods, and all transportation charges to the point of delivery.
c.i.f.e.	(named port) Cost, insurance, freight and exchange to a named port. This is the same as c.i.f. with the additional provision that the seller guarantees the buyer against loss due to a decline in the rate of exchange.
Clg.	Ceiling
Clr.	Clear
CM	Center matched; i. e., the tongue and groove joints are worked along the center of the edges of the piece.
Com.	Common
Coop.	Cooperage (stock)
Csg.	Casing
Ctg.	Crating
cu.ft.	Cubic foot
Cust.	Custom (sawed)
CV1S&E	Edge and center V one side; i. e., surfaced one or two sides and with a longitudinal edge and center V-shaped groove on a surfaced face.
CV2S&E	Edge and center V two sides; i. e., all four sides surfaced and with a longitudinal edge and center V-shaped groove on the two faces.

D&CM	Dressed (one or two sides) and center matched.
D&H	Dressed and headed; i. e., dressed one or two sides and worked to tongue and groove joints on both the edge and the ends.
D&M	Dressed and matched; i. e., dressed one or two sides and tongued and grooved on the edges. The match may be center or standard.
D&SM	Dressed (one or two sides) and standard matched.
D2S&CM	Dressed two sides and center matched.
D2S&M	Dressed two sides and (center or standard) matched.
D2S&SM	Dressed two sides and standard matched.
Dim.	Dimension
D.S.	Drop siding
E.	Edge
ECM	Ends center matched
EM	End matched—either center or standard
ESM	Ends standard matched
exp.	Export (lumber or timber)
FAS	Firsts and Seconds—a combined grade of the two upper grades of hardwoods.
f.a.s. vessel	(named port) Free alongside vessel at a named port. Term used when the seller desires to quote a price covering delivery of the goods alongside a vessel and within reach of its loading tackle.
f.bk.	Flat back
fcty.	Factory (lumber)
F.G.	Flat grain
Flg.	Flooring
f.o.b.	(named shipment point) Free on board at a named shipping point. Term used when the price quoted applies only to an inland shipping point and the seller merely undertakes to load the goods on or in cars or lighters furnished by the railroad company serving the industry, or most conveniently located to the industry, without other designation as to routing.
f.o.b.	(named point) Freight prepaid to (named point). Free on board at a named point and freight prepaid to a named point. Term used when the seller quotes a price including transportation charges to a given point without assuming responsibility for the goods after obtaining a clean bill of lading at point of origin.
f.o.b.	(named point) Freight allowed to (named point). Free on board at a named point and freight allowed to a named point. Term used where the seller wishes to quote a price from which the buyer may deduct the cost of transportation to the point of destination, without the seller assuming responsibility for the goods after obtaining a clean bill of lading at the point of origin.
f.o.b. cars	(named destination point) Free on board cars at a named destination point. Term used when the seller desires to quote a price covering the transportation of the goods to a given point, assuming responsibility for loss and/or damage up to that point.
f.o.b. cars	(named point) Free on board cars at a named point less carload lots. Term used when the goods on which a price is quoted to a given point, constitutes less than a carload lot.
f.o.b.	(named port) Lighterage free. Free on board at a named port with lighterage free. Term used when

	seller desires to quote a price which will include the expense of transportation of the goods by rail to the seaboard, including lighterage.
f.o.b. vessel	(named port) Free on board vessel at a named port. Term used when the seller desires to quote a price covering all expenses up to and including delivery of the goods upon a vessel at a named port.
f.o.k.	Free of knots.
f.o.w.	First open water.
Frm.	Framing.
ft.	Foot or feet. Also one accent ('). See symbols.
ft. b.m.	Feet board measure.
ft. s.m.	Feet surface measure.
Furn.	Furniture (stock).
G.R.	Grooved roofing.
H.bk.	Hollow back.
Hdl.	Handle (stock).
hdwd.	Hardwood.
Hrt.	Heart.
Hrtwd.	Heartwood.
1s&2s	One and Twos—a combined grade of the hardwood grades of firsts and seconds.
Impl.	Implement (stock).
in.	Inch or inches. Also two accent marks ("). See symbols.
KD	Kiln-dried.
k.d.	Knocked down.
lbr.	Lumber.
l.c.l.	Less carload lots.
lgth.	Length.
lgr.	Longer.
lin. ft.	Linear foot; i. e., 12 inches.
LR	Log run.
LR,MCO	Log run, mill culls out.
Lth.	Lath.
M.	Thousand.
M. b.m.	Thousand (feet) board measure.
MCO	Mill culls out.
Merch.	Merchantable.
m. l.	Mixed lengths.
Mldg.	Moulding.
MR	Mill run.
M.s.m.	Thousand (feet) surface measure.
m.w.	Mixed widths.
No.	Number.
Ord.	Order.
P.	Planed.
Pat.	Pattern.
Pky.	Pecky.
Pln.	Plain, as plain sawed.
Pn.	Partition.
Prod.	Production.
Qtd.	Quartered—when referring to hardwoods.
rdm.	Random.
res.	Resawed.
Rfg.	Roofing.
Rfrs.	Roofers.
rip.	Ripped.
r.l.	Random lengths.
rnd.	Round.
R. Sdg.	Rustic siding.
r.w.	Random widths.

S&E	Surfaced one side and one edge.
S1E	Surfaced one edge.
S2E	Surfaced two edges.
S1S	Surfaced one side.
S2S	Surfaced two sides.
S1S1E	Surfaced one side and one edge.
S2S1E	Surfaced two sides and one edge.
S1S2E	Surfaced one side and two edges.
S4S	Surfaced four sides.
S4SCS	Surfaced four sides with a calking seam on each edge.
S&CM	Surfaced (one or two sides) and center matched.
S&M	Surfaced and matched; i. e., surfaced one or two sides and tongued and grooved on the edges. The match may be center or standard.
S&SM	Surfaced (one or two sides) and standard matched.
S2S&CM	Surfaced two sides and center matched.
S2S&M	Surfaced two sides and (center or standard), matched.
S2S&SM	Surfaced two sides and standard matched.
Sap.	Sapwood.
SB	Standard bead.
Sd.	Seasoned.
Sdg.	Siding.
Sel.	Select.
S. E. Sdg.	Square edge siding.
s.f.	Surface foot; i. e., an area of one square foot.
Sftwd.	Softwood.
Sh. D.	Shipping dry.
Ship.	Shipment or shipments.
Shlp.	Shiplap.
s. m.	Surface measure.
SM	Standard matched.
smkd.	Smoked (dried).
smk.stnd.	Smoke stained.
s.n.d.	Sap no defect.
snd.	Sound.
sq.	Square.
Sq.E&S	Square edged and sound.
sqrs.	Squares.
Std.	Standard.
stnd.	Stained.
stk.	Stock.
stp.	Stepping.
S.W.	Sound wormy.
Symbols:	"—inch or inches, as 12". '—foot or feet, as 12'. ×—by, as 6 × 8 timber. 4/4, 5/4, 6/4, 8/4, etc. = 1 inch, 1¼ inches, 1½ inches, 2 inches, etc., when referring to the size of lumber.
T&G	Tongued and grooved.
TB&S	Top bottom, and sides.
Tbrs.	Timbers.
V1S	V one side; i. e., a longitudinal V-shaped groove on one face of a piece of lumber.
V2S	V two sides; i. e., a longitudinal V-shaped groove on two faces of a piece of lumber.
V.G.	Vertical grain.
w.a.l.	Wider, all lengths.
Wth.	Width.
wdr.	Wider.
Wgn.	Wagon (stock).
wt.	Weight.

AMERICAN LUMBER STANDARDS FOR SOFTWOOD LUMBER

Classification

1. For the purposes of simplification of sizes and grades, and of equalizing, among species used for similar general purposes, the grades of a similar name, lumber shall be classified by principal uses into (a) yard lumber, (b) structural timbers, (c) shop or factory lumber.

Note.—See definitions for further details of various kinds of lumber.

Yard Lumber

2. The term "yard lumber" as here used means lumber that is manufactured and classified into those sizes, shapes, and qualities required for ordinary construction and general purpose uses. Heavy timbers for structural purposes, softwood factory lumber, hardwood factory lumber, and other special-use materials are not considered yard stock.

GRADE STANDARDS

Grades

3. On the basis of quality, yard lumber is divided into two main divisions: (a) Select lumber, and (b) Common lumber.

These are again divided into two classes—

Select lumber into
- (1) that suitable for natural finishes and
- (2) that suitable for paint finishes;

Common lumber into
- (1) that which can be used without waste and
- (2) that which permits some waste. Each of these four classes is further divided into quality classes or grades.

SELECT LUMBER

Select Lumber

4. Lumber which is generally clear, containing defects limited both as to size and number and which is smoothly finished and suitable for use as a whole for finishing purposes or other uses in which large, clear pieces are required, shall be considered Select Lumber.

5. Two classes shall be recognized. The first shall be suitable for natural finishes. The second class permits similar defects, and, in addition, blemishes of somewhat greater extent than those of the first class, but of a type which can be covered by paint.

Grade names are A, B, C, and D.

COMMON LUMBER

Common Lumber

6. Lumber containing numerous defects and blemishes which preclude it from use for finishing purposes, but which is suitable for general utility and construction purposes shall be considered Common Lumber.

7. Two general classes shall be recognized. The first shall be suitable for use as a whole for purposes in which surface covering or strength is required. Defects and blemishes permitted in this class must be sound. The second class permits very coarse defects which may cause waste in the use of the piece.

Board Grade Names: No. 1 Common, No. 2 Common, No. 3 Common, No. 4 Common, and No. 5 Common.

Dimension Grade Names: No. 1 Common, No. 2 Common, and No. 3 Common.

BASIC GRADE CLASSIFICATION FOR YARD LUMBER

8.

- Total products of a typical log arranged in series according to quality as determined by appearance.
  - SELECT Lumber of good appearance and finishing qualities
    - Suitable for natural finishes
      - Grade A—Practically free from defects
      - Grade B—Allows a few small defects or blemishes.
    - Suitable for paint finishes
      - Grade C—Allows a limited number of small defects or blemishes that can be covered with paint.
      - Grade D—Allows any number of defects or blemishes which do not detract from a finish appearance, especially when painted.
  - COMMON Lumber containing defects or blemishes which detract from a finish appearance but which is suitable for general utility and construction purposes
    - Lumber suitable for use without waste
      - No. 1 Common—Sound and tight knotted stock. Size of defects and blemishes limited. May be considered watertight lumber.
      - No. 2 Common—Allows large and coarse defects. May be considered grain-tight lumber.
    - Lumber permitting waste
      - No. 3 Common—Allows larger and coarser defects than No. 2 and occasional knot holes.
      - No. 4 Common—Low quality lumber admitting the coarsest defects such as rot and holes.
      - No. 5 Common—Must hold together under ordinary handling.

Refer to Regional Associations

9. With the above as a basis the various regional lumber manufacturers' associations have published grading rules in details for their products and reference should be made to these rules in interpreting the practical application of these divisions of lumber into quality classes.

10. As in the case of definitions, some of the provisions vary slightly from the American Lumber Standards and the particular rules under which shipment is to be made should be considered in making contracts.

GENERAL PROVISIONS

Inspection Rules Not Arbitrary Rules

11. No arbitrary rules for the inspection of lumber can be maintained with satisfaction. The variations from any given rule are numerous and suggested by practical common sense, so nothing more definite than the general features of different grades should be attempted by rules of inspection.

Variation in Grading and Inspection

12. The grading of lumber cannot be considered an exact science, because it is based on a visual inspection of each piece and on the judgment of the grader. The provisions of these specifications, however, are sufficiently explicit to establish 5 per cent below grade as a reasonable variation between graders.

Suitability for Use

13. All yard lumber is graded with reference to its suitability for general use as yard lumber. With this in view, each piece is considered and its grade determined by its general character, including the location and sum of all of its defects and blemishes. Material not conforming to standard sizes or grades shown herein and that intended for special uses, shall be covered by special contract and inspection.

Better Face or Surfaced Side

14. Except in dimension, the grade of yard lumber, rough or surfaced two sides, shall be determined from the better or face side of the piece, and lumber which is surfaced one side only shall be graded from the surfaced side.

Poorest Piece

15. The rules for yard lumber prescribe the number and extent of defects and blemishes in the poorest pieces admissible in each grade. A grade should be representative, however, and not made up of only low line pieces.

Area of Piece

16. The number of defects and blemishes permitted varies as the area of the piece to be graded increases or diminishes in respect to the basic size or area specified, but the size of the defects must not exceed that allowed by the grading rules.

Combinations of Defects

17. When defects or blemishes or combinations thereof, not described in these grading rules are encountered, they will be considered as equivalent to known defects according to their damaging effect upon the piece in the grade under consideration.

Meaning of Equivalent

18. Equivalent means equal, and in construing and applying these rules, the defects allowed, whether specified or not, are understood to be equivalent in damaging effect to those mentioned applying to the stock under consideration.

Imperfections Removed in Dressing

19. Imperfections in rough stock which can be removed in dressing to standard size shall not be considered in determining the grade under these rules.

Defects in Rough and Dressed Stock

20. Defects admissible in rough stock shall be the same as those applying to dressed stock of like kind and grade and, in addition, such other defects as will disappear in dressing such stock to standard sizes shall be allowed.

Vertical Grain

21. Material shall be considered edge grain (vertical grain) when the rings (so-called grain) form an angle of 45 degrees or more with the surface of the piece. When the angle becomes less than 45 degrees at any point, the material shall be known as flat (slash) grain.

Mixed Grades

22. Mixed grades other than the two highest recognized grades for each species, not specifying the proportion of each grade, are not American Lumber Standard grades.

LUMBER SEASONING

23. Specifications dealing with lumber seasoning and moisture content shall be developed by each regional manufacturers' association in accordance with its own conditions and the requirements of the users of its products. Such specifications adopted from time to time by any regional association shall be filed with the Central Committee on Lumber Standards for approval.

SIZE STANDARDS

Basis of Measurement of Sizes

24. Dressed dimensions shall apply to lumber in the condition of seasoning as sold and shipped.

Finished Sizes

25. The thickness and width of finished lumber, S1S or S2S and/or S1E or S2E, shall be in accordance with the following tables:

Finish, Common Boards and Strips, Dimension and Heavy Joist

(The thicknesses apply to all widths and the widths to all thicknesses)

Product	*Size, board measure*		*Dressed dimensions*		
	Thickness Inches	*Width Inches*	*Yard Thickness Inches*	*Industrial Thickness Inches*	*Width Inches*
Finish		3	⁵⁄₁₆		2⅝
		4	⁷⁄₁₆		3½
		5	⁹⁄₁₆		4½
		6	¹¹⁄₁₆		5½
	1	7	²⁵⁄₃₂	²⁶⁄₃₂	6½
	1¼	8	1¹⁄₁₆		7¼
	1½	9	1⁵⁄₁₆		8¼
	1¾	10	1⁷⁄₁₆		9¼
	2	11	1⅝	1⁶⁄₈	10¼
	2½	12	2⅛		11¼
	3		2⅝		
Common Boards and Strips	1	3	²⁵⁄₃₂	²⁶⁄₃₂	2⅝
	1¼	4	1¹⁄₁₆		3⅝
	1½	5	1⁵⁄₁₆		4⅝
		6			5⅝
		7			6⅝
		8			7½
		9			8½
		10			9½
		11			10½
		12			11½
Dimension and Heavy Joist	2	2	1⅝	1⁶⁄₈	1⅝
	2½	4	2⅛		3⅝
	3	6	2⅝		5⅝
	4	8	3⅝		7½
		10			9½
		12			11½

Siding, Flooring, Ceiling, Partition, Shiplap, and Dressed and Matched

26.

(The thicknesses apply to all widths and the widths to all thicknesses except as modified by footnote[1])

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[1] In tongued and grooved Flooring and in tongued and grooved and shiplapped Ceiling ⁵⁄₁₆", ⁷⁄₁₆", and ⁹⁄₁₆" thick, board measure, the tongue or lap shall be ³⁄₁₆ inch wide, with the over-all widths ³⁄₁₆ inch wider than the face widths shown above. In all other patterned material, ¹¹⁄₁₆", ¾", 1", 1¼", and 1½" thick, board measure, the tongue shall be ¼ inch wide in tongued and grooved lumber, and the lap ⅜ inch wide in shiplapped lumber, with the over-all widths ¼ inch and ⅜ inch wider, respectively, than the face widths shown above.

Product	*Size, board measure*		*Dressed dimensions*	
	Thickness Inches	*Width Inches*	*Thickness Inches*	*Width Inches.*
Bevel Siding				
		4	7/16 (minimum) x 3/16	3½
		5	10/16 x 3/16	4½
		6		5½
Wide Bevelled Siding				
		8	7/16 (minimum) x 3/16	7¼
		10	9/16 x 3/16	9¼
		12	11/16 x 3/16	11¼
Rustic and Drop Siding (shiplapped)				
		4	9/16	3⅛
		5	¾	4⅛
		6		5 1/16
		8		6⅞
Rustic and Drop Siding (dressed and matched)				
		4	9/16	3¼
		5	¾	4¼
		6		5 3/16
		8		7
Flooring				
		2	5/16	1½
		3	7/16	2⅜
		4	9/16	3¼
		5	25/32	4¼
	1	6		5 3/16
	1¼		1 1/16	
	1½		1 5/16	
Ceiling				
		3	5/16	2⅜
		4	7/16	3¼
		5	9/16	4¼
		6	11/16	5 3/16
Partition				
		3	¾	2⅜
		4		3¼
		5		4¼
		6		5 3/16
Shiplap				
	1	4	25/32	3⅛
		6		5⅛
		8		7⅛
		10		9⅛
		12		11⅛
Dressed and Matched				
	1	4	25/32	3¼
	1¼	6	1 1/16	5¼
	1½	8	1 5/16	7¼
		10		9¼
		12		11¼

Factory Flooring, Heavy Roofing, Decking and Sheet Piling

27.

(The thicknesses apply to all widths and the widths to all thicknesses)

	Size, board measure			*Dressed dimensions*	
Thickness Inches	*Width Inches*	*Thickness Inches*	*D&M Inches*	*Shiplapped Inches*	*Groved for splines Inches*
2	4	1⅝	3⅛	3	3½
2½	6	2⅛	5⅛	5	5½
3	8	2⅝	7⅛	7	7½
4	10	3⅝	9⅛	9	9½
	12		11⅛	11	11½

The over-all widths of patterned material 2 inches and thicker, board measure, may be computed on the basis that the tongue shall be ⅜ inch wide in tongued and grooved lumber, and the lap ½ inch wide in shiplapped lumber.

ROUGH DRY SIZES

Thickness Standard Yard Board
Standard Industrial Board

28. The standard rough dry thickness of the standard yard board shall be not less than 29/32 with an allowance of 20 per cent of the shipment, which may be not less than 28/32 inch, and the standard rough dry thickness of the standard industrial board shall be not less than 30/32 inch with an allowance of 10 per cent of the shipment, which may be not less than 29/32 inch.

Thick Boards

29. The standard rough dry thickness of finish, common boards, and dimension of standard sizes 1¼ inches and thicker, board measure, shall not be less than ⅛ inch thicker than the corresponding standard finished dry thickness, with an allowance of 20 per cent of the shipment, which may not be less than 3/32 inch thicker than the corresponding standard finished dry thickness.

Widths

30. The standard width of rough dry finish of 3-inch width, board measure, shall be not more than ¼ inch less than the nominal width, widths 4 to 7 inches, inclusive, board measure, shall be not more than ⅜ inch less than the nominal widths and widths 8 to 12 inches, inclusive, board measure, shall be not more than ⅝ inch less than the nominal widths, and the rough dry widths of common boards and dimension 7 inches and narrower, shall be not more than ¼ inch less than the nominal widths, and the widths 8 to 12 inches, board measure, shall be not more than ⅜ inch less than the nominal widths.

LENGTHS

Lengths

31. With the exception of the following enumerated odd lengths, no odd lengths are considered standard in yard lumber.

2 by 4 inches, 6 and 8 inches—9 and 11 feet.
2 by 8 inches, and 10 inches—13 feet.
2 by 10 inches—15 feet.
8 by 8 inches, 10 by 10 inches, 10 by 12 inches, 12 by 12 inches, 14 by 14 inches, 16 by 16 inches, 18 by 18 inches—11 and 13 feet.
6 by 6 inches, 6 by 18 inches, 8 by 16 inches, 8 by 18 inches—15 and 17 feet.
*7 by 16 inches, 9 by 16 inches, 9 by 18 inches—15 and 17 feet.

WORKINGS

Standard Workings

32. The Standard workings of Flooring, Ceiling, Partition, Surfaced Two Sides and Center Matched, Drop Siding, Heavy Flooring, Grooved for Splines, Shiplap, and Byrkit Lath, shall be considered Standard. All other workings shall be considered Special.

End Trimming

33. Unless otherwise stated in the contract of purchase, yard lumber shall be double end-trimmed with a tolerance of not to exceed 3 inches in excess of nominal length.

DESCRIPTION, MEASUREMENT AND TALLY

Tally, Standard and Special

34. The thicknesses and widths of lumber as specified in Section 25, 26, 27, 28, 29 and 30 shall be considered standard. All other sizes shall be considered special.

Description

35. Lumber of standard size shall be described by those standard dimensions.

Thin Lumber

36. Lumber of standard size shall be tallied board measure. On lumber of standard thickness less than 1 inch (board measure), the board-foot measurement shall be based on the surface dimensions.

Tally of Dressed Lumber

37. The board measurement of dressed lumber of standard size shall be based upon the corresponding nominal dimensions of rough green lumber.

Special Size

38. Lumber finished to special size shall be counted (tallied) as of the standard rough size necessarily used in its manufacture.

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*Not mentioned in American Lumber Standards, but necessary in railroad use.

Stock Sizes

39. Material shipped on stock sizes shall be tallied by the number of pieces of each size and length in the shipment.

40. In shipments measured on board measure a piece tally in board feet shall be made.

Fractions of Board Foot

41. In material measured with a board rule on actual widths, pieces measuring to the even half foot shall be alternately counted as of the next higher and lower foot count, fractions below the one-half foot shall be dropped, fractions above the one-half foot shall be counted as of the next higher foot.

SHIPPING PROVISIONS

Invoice Dimensions of Non-Standard Lumber

42. The actual thickness and width of lumber shipped when not of standard size shall be indicated on invoice.

Uneven Sawing

43. In shipment of rough boards and finish, pieces one-half inch or more above the count thickness, such as may be produced by uneven sawing, may, at the option of the buyer, be rejected, or accepted as of the next lower grade.

Average Length

44. The average length of a shipment of lumber shall be computed by dividing the total length in feet by the total number of pieces in a shipment.

Bundling

45. Each length of bundle stock shall be bundled separately.

SHINGLES

Grades

Grades

46. The basic grades of shingles shall be A, B, C, and D. The grade name shall be clearly marked on each and every bundle of wood shingles.

Sizes

Sizes

47. Sixteen-inch 6/2 shingles and 18-inch 5/2 shingles shall be eliminated.

48. Dimension shingles shall be sold full net count, no dimension shingle to be less than 1/8 inch scant of the specified width when dried.

STANDARD GRADES OF RED CEDAR SHINGLES

Random Widths

A

To be strictly clear, edge grain, and free from sap. Random widths.

24" Shingles 4/2"

49. No shingle to be narrower than 4 inches. To be packed 14/14 courses to bunch; 9 bunches to "M"; 4 bunches to "square" 7½ inches exposure, 3 bunches to "square" 10 inches exposure. Bunches must measure 7 inches across butts when green, 6¾ inches when dry.

18" Shingles 5/2¼"

50. No shingle to be narrower than 3 inches. If packed by "M" must count 20/20 courses to bunch, 5 bunches to "M." Bunches must measure 9 inches across butt when green, 8¾ inches when dry. If packed by the "square" must count 18/18 courses to bunch, 4 bunches to square. Bunches must measure 8⅛ inches across butts when green, 7⅞ inches when dry.

16" Shingles 5/2"

51. No shingle to be narrower than 3 inches. If packed by "M" must count 25/25 courses to bunch, 4 bunches to "M." Bunches must measure 10 inches across butts when green, 9¾ inches when dry. If packed by the "square" must count 20/20 courses to bunch, 4 bunches to square, or 5 to "M." Bunches must measure 8 inches across butts when green 7¾ inches when dry.

B

52. To be strictly clear. Not less than 50 per cent edge grain, with not to exceed ½ inch sap on any portion of the 5 inches measured from the butt, on one edge only.

24" Shingles 4/2"

53. None.

18" Shingles 5/2¼"

54. No shingle to be narrower than 3 inches. If packed by "M" must count 20/20 courses to bunch, 5 bunches to "M." Bunches must measure 9 inches across butts when green, 8¾ inches when dry. If packed by the "square" must count 18/18 courses to bunch, 4 bunches to square. Bunches must measure 8⅛ inches across butts when green, 7⅞ inches when dry.

16" Shingles 5/2"

55. No shingle to be narrower than 3 inches. If packed by "M" must count 25/25 courses to bunch, 4 bunches to "M." Bunches must measure 10 inches across butts when green, 9¾ inches when dry. If packed by "square" must count 20/20 courses to bunch, 4 bunches to square, or 5 to "M." Bunches must measure 8 inches across butts when green, 7¾ inches when dry.

C

56. Ten-inch clear butts and better for 16 and 18-inch shingles and 16-inch clear butts and better for 24-inch shingles not permitted in higher grades. Sap permitted.

24″ Shingles 4/2″

57. No shingle to be narrower than 3 inches. To be packed 14/14 courses to bunch; 9 bunches to "M"; 4 bunches to "square" 7½ inches exposure, 3 bunches to "square" 10 inches exposure. Bunches must measure 6¾ inches across butts when green, 6½ inches when dry.

18″ Shingles 5/2¼″

58. No shingle to be narrower than 2½ inches. If packed by "M" must count 20/20 courses to bunch, 5 bunches to "M." Bunches must measure 8¾ inches across butts when green, 8½ inches when dry. If packed by the "square" must count 18/18 courses to bunch, 4 bunches to square. Bunches must measure 7⅞ inches across butts when green, 7⅝ inches when dry.

16″ Shingles 5/2″

59. No shingle to be narrower than 2½ inches. If packed by "M" must count 25/25 courses to bunch, 4 bunches to "M." Bunches must measure 9¾ inches across butts when green, 9½ inches when dry. If packed by the "square" must count 20/20 courses to bunch, 4 bunches to square, or 5 to "M." Bunches must measure 7¾ inches across butts when green, 7½ inches when dry.

D

60. Six-inch clear butts for 16 and 18-inch shingles, 10-inches clear butts for 24-inch shingles. Sap permitted.

24″ Shingles 4/2″

No shingles to be narrower than 2 inches. Permits shims and feather tips 20 inches long. To be packed 14/14 courses to bunch; 9 bunches to "M"; 4 bunches to "square" 7½ inches exposure, 3 bunches to "square" 10 inches exposure. Bunches must measure 6¾ inches across butts when green, 6½ inches when dry.

18″ Shingles 5/2¼″

61. No shingle to be narrower than 2 inches. Permits shims and feather tips 16 inches long. If packed by "M" must count 20/20 courses to bunch, 5 bunches to "M." Bunches must measure 8¾ inches across butts when green, 8½ inches when dry. If packed by the "square" must count 18/18 courses to bunch, 4 bunches to square. Bunches must measure 7⅞ inches across butts when green, 7⅝ inches when dry.

16″ Shingles 5/2″

62. No shingle to be narrower than 2 inches. Permits shims and feather tips 14 inches long. If packed by "M" must count 25/25 courses to bunch, 4 bunches to "M." Bunches must measure 9½ inches across butts when

green, 9¼ inches when dry. If packed by the "square" must count 20/20 courses to bunch, 4 bunches to square, or 5 to "M." Bunches must measure 7½ inches across butts when green, 7¼ inches when dry.

GENERAL RULES

63. All A and B grade shingles must be parallel (a 16 or 18 inch A or B shingle not over ¼ inch off parallel or a 24-inch A shingle not over ⅜ inch off parallel shall be considered parallel), uniform in thickness, and well manufactured. This means shims and feather tips are not permitted; smoothness of faces and butts must be first-class. Badly cross-grained shingles not permitted.

64. No full flat-grain shingle wider than 10 inches permitted in grade B, and no shingle wider than 14 inches permitted in A and B grades; 1 inch over and under in length is permitted in 10 per cent. Shingles cut from equalized blocks may be ¼ inch less than the standard length. C grade admits slight irregularities in thickness. A shingle in C grade, not over ⅜ inch off parallel, shall be considered parallel.

65. When reference is made to edge grain, percentage of edge grain shall be determined by the proportion of actual linear measurement of edge grain to full linear measurement of shingles. In 16 and 18 inch A and B grades not more than 10 per cent of any shipment may be less than 4 inches in width.

66. All shingles to be packed in straight courses in regulation frames 20 inches in width with band sticks not less than 19½ inches long. Openings shall not exceed an average of 1 inch to the course in random width shingles. Discrepancy in inspection in any grade shall not exceed 4 per cent.

67. Color of wood is not a defect in any grade.

SOFTWOOD FACTORY AND SHOP LUMBER

GENERAL PROVISIONS

Grade by Cuttings

68. The grade of factory lumber shall be determined by the percentage of the area of each board or plank available in cuttings of specified or given minimum sizes and qualities, except in the upper grades of shop lumber of all thicknesses.

69. The grade of softwood factory boards or plank or shop lumber shall be determined from the poor face, although the quality of both sides of each cutting must be considered.

70. When lumber is crooked, bowed, cupped or twisted, the cuttings must be so laid out as to be flat and straight along the edges.

Measurement—Fractions

71. Board measurement shall be used in measuring factory lumber. When measured with a board rule, pieces measuring to the even half foot shall be alternately counted as of the next higher and the next lower surface foot; fractions below the half foot shall be dropped, and fractions above the half foot shall be counted as of the next higher foot.

Thicker Than 1"

72. To determine the board foot contents of material thicker than 1 inch the surface measure should be multiplied by the nominal thickness in inches and fractions of an inch.

Based Upon Rough Green

73. The board measurement of dressed factory lumber of standard size shall be based upon the corresponding standard dimension of rough green lumber.

LUMBER SEASONING

74. Specifications dealing with lumber seasoning and moisture content shall be developed by each regional manufacturers' association in accordance with its own conditions and the requirements of the users of its products. Such specifications adopted from time to time by any regional association shall be filed with the Central Committee on Lumber Standards for approval.

SIZES

Basis of Measurement of Sizes

75. Dressed dimensions shall apply to lumber in the condition of seasoning as sold and shipped.

DRESSED THICKNESSES

Thicknesses

76. The following thicknesses of factory lumber shall be considered standard. All other thicknesses shall be considered special.

Finished thicknesses, S1S or S2S.

Size Board Measure Inches	*Standard Inches*
1	25/32
1¼	1 5/32
1½	1 13/32
2	1 25/32
2¼	2⅛
2½	2⅜
3	2⅝
4	3⅝

WIDTHS

Widths

77. Standard widths shall be five inches and over; factory lumber is usually shipped in random lengths, though specified widths may be shipped. Five-inch widths must be full size in the rough dry condition.

LENGTHS

Lengths

78. Standard lengths shall be six feet and over in multiples of one foot, except in box lumber which shall be 4 feet and over.

FACTORY PLANK

Door Cuttings

79. In determining the percentage of door cuttings, consideration must be given to the fact that planks are to be ripped full length before crosscutting, in such manner as will yield the highest grade and largest percentage of door cuttings, except in such cases where planks will yield a higher value by first being cross-cut for rails. In instances where stock is cross-cut for rails and some of the stock so obtained contains stiles or muntins or top rails, which can be obtained by ripping this cross-cut stock, the door cuttings so obtained may be figured in when determining percentages.

GRADE CLASSIFICATIONS FOR SOFTWOOD FACTORY PLANK

80.

- FACTORY PLANK
  Factory lumber graded with reference to its use for doors, sash and other cuttings.
  - FACTORY CLEARS
    Upper grades of factory plank containing a high percentage of best quality cuttings.
    - No. 1 and 2 Clear Factory—Lumber practically clear in wide sizes, to contain not less than 85 per cent of No. 1 door cuttings; not including pieces with over 2 muntins, or muntins only.
    - No. 3 Clear Factory—Lumber containing not less than 70 per cent of No. 1 door cuttings; not including pieces with over 2 muntins, or muntins only.
  - SHOP
    Lower grades of factory plank yielding smaller percentages in smaller and lower quality cuttings.
    - No. 1 Shop—Lumber of high quality factory grade containing not less than 50 per cent of No. 1 door cuttings; allowing, if necessary, one No. 2 stile in any piece, but no pieces with over two muntins, or muntins only.
    - No. 2 Shop—Lumber containing not less than 25 per cent of No. 1 door cuttings, or 40 per cent of No. 2 door cuttings, or 33⅓ per cent of mixed door cuttings.
    - No. 3 Shop—Lumber of a shop type below the grade of No. 2 Shop and better than box lumber.

QUALITY OF CUTTINGS

Cuttings No. 1 and 2

81. In determining the grades of Factory Plank, two grades of cuttings shall be recognized. These shall be known as No. 1 and No. 2 Cuttings and shall conform to the following rules.

Defects

82. No. 1 Cuttings shall be free from defects on both sides. No restrictions shall be made upon bright sapwood.

83. No. 2 Cuttings shall admit any one of the following defects:

84. Light blue stain on one side, not larger in extent than half-half the area of the side.

85. Medium brown kiln or heart stain covering half the surface on one face, or a greater area of lighter stain, or a proportionate amount on two sides.

86. A small sound and tight knot which does not exceed ⅝ of an inch in diameter.

87. A small pitch pocket not over ⅛ of an inch wide nor over 2 inches long in West Coast woods and not over ⅛ of an inch wide nor over 1 inch long in Idaho White Pine, Pondosa Pine, California White Pine and Sugar Pine.

88. One or more small season checks whose combined length does not exceed 8 inches.

89. Light pitch or small streaks that do not form a pronounced defect.

90. Slightly torn grain on one side.

SIZES OF CUTTINGS

Size of Stiles

91. Stiles shall be 5 inches and 6 inches wide by 6 feet 8 inches to 7 feet 6 inches long. They may be either No. 1 or No. 2 in quality.

Bottom Rails

92. Bottom rails shall be 9 inches and 10 inches wide by 2 feet 4 inches to 3 feet long. They may be either No. 1 or No. 2 in quality.

Muntins

93. Muntins shall be 5 inches and 6 inches wide by 3 feet 6 inches to 4 feet long. They may be either No. 1 or No. 2 in quality.

Top Rails

94. Top rails shall be 5 inches and 6 inches wide by 2 feet 4 inches to 3 feet long. They must be of No. 1 Cutting quality but shall be considered as No. 2 Cuttings.

Sash Cuttings

95. Sash Cuttings shall be 2½ inches and 3½ inches in width by 28 inches and over in length.

Cuttings and Area Use

96. In computing the area of cuttings in each piece of Factory Plank the sizes listed below shall be used. After each cutting size is shown the exact surface area in square feet. For convenience in computing, the figures shown on the right, representing the area to the nearest ¼ square foot, shall be used.

STILES

Size of cutting in board or plank	*Actual Area in Sq. Ft.*	*Nominal Area to be used in application of grading rules*
5"x6'8"	2.78	3
5"x6'10"	2.85	
5"x7'0"	2.92	
5"x7'2"	2.99	
5"x7'4"	3.06	
5"x7'6"	3.13	
6"x6'8"	3.33	3¼
6"x6'10"	3.42	3½
6"x7'0"	3.50	
6"x7'2"	3.58	
6"x7'4"	3.67	3¾
6"x7'6"	3.75	

BOTTOM RAILS

9"x2'4"	1.75	1¾
9"x2'6"	1.875	
9"x2'8"	2.0	2
9"x2'10"	2.125	
9"x3'0"	2.25	2¼
10"x2'4"	1.95	2
10"x2'6"	2.08	
10"x2'8"	2.22	2¼
10"x2'10"	2.36	
10"x3'0"	2.50	2½

MUNTINS

5"x3'6"	1.46	1½
5"x3'8"	1.53	
5"x3'10"	1.60	
5"x4'0"	1.67	1¾
6"x3'6"	1.75	
6"x3'8"	1.83	
6"x3'10"	1.92	2
6"x4'0"	2.0	

TOP RAILS

5"x2'4"	.97	1
5"x2'6"	1.04	
5"x2'8"	1.11	
5"x2'10"	1.18	1¼
5"x3'0"	1.25	
6"x2'4"	1.17	
6"x2'6"	1.25	
6"x2'8"	1.33	
6"x2'10"	1.42	1½
6"x3'0"	1.50	

GRADE CLASSIFICATIONS FOR SOFTWOOD SHOP LUMBER

97.

SHOP LUMBER

Shop Lumber graded for cuttings of minimum and larger sizes or for permissible defects with reference to its use for general cut-up purposes.

- FOR SHOP LUMBER ONE INCH IN THICKNESS*
  - Select
    Lumber to contain not less than 70% of (a) and/or (b) cuttings.
  - Shop
    Lumber to contain not less than 50% of (a) and/or (b) cuttings.
- FOR SHOP LUMBER OF ALL THICKNESSES†
  - Tank and Boat Stock—Lumber admitting sound defects that do not impair the usefulness of each piece for the use intended.
  - First and Seconds—Lumber of C Select or Better quality on the reverse side, suitable for remanufacture into products requiring both faces of good quality.
  - Selects—Lumber of C Selects or Better quality on the face side suitable for remanufacture into products requiring one face of good quality.
  - No. 1 Shop—Lumber to contain not less than 60 per cent of (a) and/or (b) cuttings.
  - No. 2 Shop—Lumber to contain not less than 40 per cent of (a) and/or (b) cuttings.
  - Box—Lumber below the grade of No. 2 Shop, to contain not less than 66⅔ per cent sound cuttings not less than 3 inches wide and 18 inches long.

98. In determining the grades of either shop or cut-up lumber based on cuttings, two grades and sizes of cuttings shall be recognized and shall conform to the following rules:

Size of Cuttings

99. (a) Cuttings shall be 9½ inches wide or wider by 18 inches long or longer.

100. (b) Cuttings shall be 5 inches wide or wider by 3 feet long or longer.

Quality of Cuttings

101. (a) Cuttings less than 3 feet long shall be free from all defects on both sides. No restriction need be made upon bright sapwood.

102. (a) Cuttings 3 feet long or longer and (b) cuttings shall have a C Select or Better face in all softwoods except Douglas fir, Sitka spruce and

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*For Northern, Western, and California Pine, and West Coast woods.

†For Cypress, Redwood, and North Carolina Pine.

West Coast hemlock, where the face of the cuttings shall be equal to B or Better Finish.

LUMBER INSPECTION PROVISIONS AND SERVICE

Use Shipping Form

103. Lumber must be inspected, accepted or rejected, on grade in the form in which it is shipped. Any subsequent change in manufacture, mill work or dry kilning will prohibit an inspection for the adjustment of claims except with the consent of all parties interested.

Inspection Availability

104. Official lumber association inspection service for the inspecting of lumber sold as of standard size, and standard grade, shall be available to non-members of associations, upon request and at a reasonable charge.

Re-Inspection

105. In case of complaint on account of the grade or tally of any shipment of standard size or standard grade, official lumber association re-inspection shall be available.

Special Grades

106. Official lumber association inspection shall not be required to be furnished for the inspection of "special" grades of lumber (that is, not recognized in published grading rules), and inspection service for "special" grades shall be furnished only when the exact specifications of such grades in writing are furnished to the inspector.

Certificate

107. Where buyers demand, and will pay the cost thereof, a certificate made by a certified lumber association inspector shall be furnished with each shipment so arranged for.

Complaint and Re-Inspection

108. Upon receipt of complaint from the purchaser the seller shall immediately request the association under whose rules shipment has been made to provide official re-inspection or re-tally, as the case may be, according to its inspection rules in effect at the time of execution of contract; and the purchaser shall lend all reasonable assistance to facilitate the re-inspection or re-tally.

Expense of Inspections

109. The expense of such re-inspection or re-tally may be divided between the buyer and seller, or may be borne by either, according to agreement between them, but the person calling for the re-inspection shall be responsible to the association for the costs thereof.

Complaint on Tally

110. In case of complaint involving tally, the entire item shall be held intact of re-tally.

Complaint on Grade Only

111. In cases of complaint regarding grade but not involving tally, the buyer is required to accept that portion of a shipment of lumber of standard grade or standard size, which is up to grade or of standard size, as the case may be, holding intact that portion thereof, the grade or size of which is in dispute, for official lumber association inspection; the action on the part of the buyer in accepting and using such portion of the shipment shall not be construed as his acceptance of the entire shipment; further, the buyer shall pay in accordance with the terms of sale for that portion which he accepts, but acceptance by the buyer of a part of a shipment does not prejudice his just claims on account of any unused material that is alleged by him to be below standard grade or not of standard size.

Shipment to Be Held Not Exceeding 30 Days

112. The complainant buyer shall hold disputed material intact, properly protected, for not exceeding 30 days after date of the request for official inspection, or re-inspection, and shall file complaint with seller within 10 days from receipt of shipment.

Variation of Inspections

113. Each item in a carload or a cargo shall be considered as of the grade invoiced, if, upon official association re-inspection under the grading and inspection rules under which the lumber has been graded and sold, 95 per cent thereof or more is found to be of said grade, the material below said grade to be accepted by the buyer as of its actual grade. Where the de-grades are in excess of 5 per cent of such item or where the de-grades are found upon official re-inspection to be more than one grade lower than the grade invoiced, the de-grades shall be the property of the seller. These provisions shall not apply in the case of specially worked lumber.

Qualified Inspectors

114. All grading shall be done by properly supervised and qualified graders or inspectors.

Contract Clause

115. It is recommended that sales contracts incorporate in substance the following clause:

"Shipment under this contract shall be in accordance with the American Lumber Standards as modified and adopted by the American Railway Engineering Association."

Exemption

116. In case of shipments made or received under such contracts exemption from any provision thereof shall be by special agreement and the burden of proof thereof shall be upon person claiming exemption.

INTRODUCTION TO STRUCTURAL RULES

1. The following rules for Structural Grades conform to the "Basic Provisions for the Selection and Inspection of Softwood Dimension and Timbers where Working Stresses Are Required" recommended by the Structural Timber Conference, Chicago, Ill., November 20, 1928, as approved by the Central Committee on Lumber Standards, Chicago, Ill., December 7, 1928.

2. They are complete rules, covering all conditions necessary of consideration in structural grading, and are divided into sections from which combinations are made covering specific purposes and conditions.

3. These specifications may be used for mill orders, selection from or appraisal of stock on hand in either manufacturers', middlemen's or users' stock.

4. The rules cover the following Grades and Use Classifications:

Grades: DENSE SELECT,
Douglas Fir and Southern Pine,
SELECT,
Douglas Fir,
SELECT,
Other Softwood Species except Southern Pine,
DENSE COMMON,
Douglas Fir and Southern Pine,
COMMON,
All Softwood Species.

Uses: JOIST and PLANK,
Joist, Rafters, Bracing, Scaffold Plank, Factory Flooring, etc.
BEAMS and STRINGERS,
Beams, Girders, Stringers, Bridge Ties, Caps, etc.,
POSTS and TIMBERS,
Posts, Sills, Caps, Timbers, Etc.

Optional Provisions: WANE,
Where Permissible,
SQUARE EDGES,
Where Required or Desired,
HEARTWOOD REQUIREMENT,
For Durability of Untreated Timbers,
SAPWOOD PERMISSIBILITY,
For Material to be Treated.

Sizes of Joist and Plank

Joist, Rafters, Scaffold Plank, Factory Flooring, etc.

Nominal thickness:	2″ to 4″
Nominal widths:	4″ and wider
Standard thickness:	S1S or S2S: ⅜″ off
Standard widths:	4″ to 7″, S1E or S2E: ⅜″ off
	8″ and wider, S1E or S2E: ½″ off.

Sizes of Beams and Stringers

Beams, Girders, Stringers, etc.

Nominal thickness:	5″ and thicker
Nominal widths:	8″ and wider.

Sizes of Posts and Timbers

Posts, Caps, Sills, Timbers, etc.

Nominal sizes: 6" x 6" and larger

SPECIFICATIONS FOR STRUCTURAL WOOD JOIST, PLANK, BEAMS, STRINGERS, AND POSTS

TIMBER SIZE REQUIREMENTS

Joist and Plank, Surfaced

1A. Structural Joist and Plank shall be when surfaced S1S or S2S not thinner than the nominal dimensions less ⅜ inch and when surfaced S1E or S2E not narrower than the nominal width less ⅜ inch for sizes 2 to 7 inches, inclusive, and less ½ inch for sizes 8 inches and wider.

Joist and Plank, Rough

1B. Rough Structural Joist and Plank shall be not thinner than the nominal dimensions less ¼ inch, and not narrower than the nominal width less ¼ inch for sizes 2 to 7 inches, inclusive, and less ⅜ inch for sizes 8 inches and wider.

Beams and Stringers, Surfaced

2A. Structural Beams and Stringers shall be when surfaced S1S, S1E, S2S or S4S not smaller than the nominal size less ⅜ inch for sizes 7 inches and less, and less ½ inch for sizes 8 inches and over.

Beams and Stringers, Rough

2B. Rough Structural Beams and Stringers shall be not smaller than the nominal size less ¼ inch for sizes 7 inches and less, and less ⅜ inch for sizes 8 inches and over.

Posts and Timbers, Surfaced

3A. Structural Posts and Timbers shall be when surfaced S1S, S1E, S2S or S4S not smaller than the nominal size less ⅜ inch for sizes 7 inches and less, and less ½ inch for sizes 8 inches and over.

Posts and Timbers, Rough

3B. Rough Structural Posts and Timbers shall be not smaller than the nominal size less ¼ inch for sizes 7 inches and less, and less ⅜ inch for sizes 8 inches and over.

Dressed Dimension Measured Green

4. The dressed dimensions specified in Paragraphs 1A, 2A and 3A shall be minimum dimensions when measured green.

GRADE REQUIREMENTS

Sound Wood

5. This material shall contain only sound wood, free from any form of decay, incipient or advanced, including firm red heart, dote, and rot.

GENERAL

Weight

6a. No pieces of exceptionally light weight shall be permitted in any grade.

Shake, Checks and Splits

b. Shake shall be measured on the ends of a piece. Checks and splits shall be limited as provided for shakes. No checks or combinations of checks with shakes which would reduce the strength to a greater extent than the allowable shake shall be permitted.

Pitch Pockets

c. Pitch pockets are ordinarily not defects in a structural grade. A large number, however, indicates a general lack of bond, and such a piece should be carefully examined for shakes.

Wane and Knots

d. Where wane is permitted there shall be no combination of wane and knots which would reduce the strength more than the maximum allowable knot.

Cluster Knots

e. Cluster knots and knots in groups are not permitted.

Holes

f. Knot holes and holes from other causes than knots shall be permitted as provided for knots.

Knot Measurement

g. The size of a knot shall be measured on the section of the knot appearing on the face under consideration.

Spike Knots

h. Knot sizes specified shall be applied to spike knots as well as to round knots.

Definitions of Faces

i. The faces of a piece of dimension or of a timber are the four longitudinal surfaces of the piece, sometimes further designated as "wide" faces or "narrow" faces.

j. In a piece of dimension or a timber graded for use in bending, wide faces shall be taken as vertical faces, and narrow faces as horizontal faces, unless otherwise noted.

k. When the faces of a piece of dimension or a timber are of equal width, Post and Timber grades shall be used unless otherwise noted. When such a piece of dimension or such a timber is graded for use in bending, the best faces shall be taken as the horizontal faces and should be so marked.

Definition of Edges

l. The edges of a piece of dimension or of a timber are understood to be narrower faces, and the sides the wider faces. For the locations of knots and other defects, however, the edges of a given face shall be taken to be the intersection of two adjacent faces, commonly called corners in the past.

KNOTS

JOIST AND PLANK

Wide Faces

7a. On wide faces of Joist and Plank, the size of a knot shall be measured on the mean or average diameter. The mean or average diameter of a knot shall be taken as the average of its maximum and minimum diameters. The average diameter of a spike knot shall be taken as the average of its length and its maximum width.

Narrow Faces

b. On narrow faces of Joist and Plank, the size of a knot shall be taken as its width between lines parallel to the edges of the piece.

Increase to Ends

c. The size of knots on narrow faces and at edges of wide faces of Joist and Plank may increase proportionately from the size allowed in the middle third to twice that size at the ends of the piece.

Increase to Center Line

d. The size of knots on wide faces of Joist and Plank may increase proportionately from the size allowed at the edge to that allowed at the center line.

BEAMS AND STRINGERS

Wide Faces

8a. On wide or vertical faces of Beams and Stringers the smallest diameter of a knot shall be taken as its size.

Narrow Faces

b. On narrow or horizontal faces of Beams and Stringers the size of a knot shall be taken as its width between lines parallel to the edges of the piece.

Edges of Wide Faces

c. Knots at edges of wide or vertical faces of Beams and Stringers are limited to the same size as on the adjacent narrow or horizontal faces, but the size is measured on the least diameter of the knot instead of on its width between lines parallel to the edges of the timber.

Increase to Ends

d. The size of knots on narrow or horizontal faces and at edges of wide or vertical faces of Beams and Stringers may increase proportionately from the size allowed in the middle third to twice that size at the ends of the piece.

Increase to Center Line

e. The size of knots on wide or vertical faces of Beams and Stringers may increase proportionately from the size allowed at the edge to that allowed at the center line.

POSTS AND TIMBERS

All Faces

9. In Posts and Timbers, the size of a knot shall be measured on the mean or average diameter. The mean or average diameter of a knot shall be taken as the average of its maximum and minimum diameters. The average diameter of a spike knot shall be taken as the average of its length and its maximum width.

MAXIMUM KNOTS IN DENSE SELECT AND SELECT JOIST AND PLANK

10a. KNOTS ON WIDE FACES

At edges, middle third of length	*Width of face*	*On center line of face*
¾"	4"	1¼"
1"	6"	2"
1⅜"	8"	2⅝"
1¾"	10"	3¼"
2⅛"	12"	4"
2⅜"	14"	4¼"
2½"	16"	4⅝"

b. KNOTS ON NARROW FACES OF BOXED HEART PIECES

Thickness of Piece	*Middle Third of Length*
2"	⅝"
3"	1"
4"	1¼"

c. The sum of the diameters of all knots within the center half of the length of a Joist or Plank on any face shall not exceed one and one-half times the width of the face on which they occur.

MAXIMUM KNOTS IN DENSE COMMON AND COMMON JOIST AND PLANK

11a. KNOTS ON WIDE FACES

At edges, middle third of length	*Width of face*	*On center line of face*
1"	4"	1¾"
1½"	6"	2½"
2"	8"	3⅜"
2½"	10"	4¼"
3"	12"	5⅛"
3¼"	14"	5⅝"
3⅜"	16"	6"

b. KNOTS ON NARROW FACES OF BOXED HEART PIECES

Thickness of Piece	*Middle Third of Length*
2"	⅞"
3"	1¼"
4"	1¾"

c. The sum of the diameters of all knots within the center half of the length of a Joist or Plank on any face shall not exceed two times the width of the face on which they occur.

Maximum Knots in Dense Select and Select Beams and Stringers

12a.

Narrow or horizontal face, middle third of length	*Width of face*	*Center line of wide or vertical face*
1¼″	5″	1¼″
1½″	6″	1½″
1¾″	8″	2″
2″	10″	2½″
2⅛″	12″	3″
2¼″	14″	3¼″
2⅜″	16″	3⅜″
...	18″	3⅝″
...	20″	3⅞″
...	22″	4″
...	24″	4¼″

b. The sum of the diameters of all knots within the center half of the length of a Beam or Stringer on any face shall not exceed the width of the face on which they occur.

Maximum Knots in Dense Common and Common Beams and Stringers

13a.

Narrow or horizontal face, middle third of length	*Width of face*	*Center line of wide or vertical face*
2″	5″	2″
2⅜″	6″	2⅜″
2¾″	8″	3⅛″
3⅛″	10″	4″
3⅜″	12″	4¾″
3⅝″	14″	5⅛″
3⅞″	16″	5½″
...	18″	5⅞″
...	20″	6⅛″
...	22″	6½″
...	24″	6¾″

b. The sum of the diameters of all knots within the center half of the length of a Beam or Stringer on any face shall not exceed one and one-half times the width of the face on which they occur.

Maximum Knots* in Dense Select and Select Posts and Timbers

14a.

Width of Face	*Knots*
6″	1½″
8″	2″
10″	2½″
12″	3″
14″	3¼″
16″	3⅜″
18″	3⅝″
20″	3⅞″
22″	4″
24″	4¼″

*On faces less than 6″, knots shall not exceed ¼ width of face.

b. The sum of the diameters of all knots in any 6 inches of the length of a Post or Timber shall not exceed twice the size of the maximum knot allowable, nor shall there be two of maximum allowable knots in same 6 inches of length on any one face.

MAXIMUM KNOTS* IN DENSE COMMON AND COMMON POSTS AND TIMBERS

15a.

Width of Face	*Knots*
6″	2⅜″
8″	3⅛″
10″	4″
12″	4¾″
14″	5⅛″
16″	5½″
18″	5⅞″
20″	6⅛″
22″	6½″
24″	6¾″

*On faces less than 6″, knots shall not exceed 4⁄10 width of face.

b. The sum of the diameters of all knots in any 6 inches of the length of a Post or Timber shall not exceed twice the size of the maximum knot allowable, nor shall there be two of maximum allowable knots in same 6 inches of length on any one face.

SHAKE AND CHECKS

JOIST AND PLANK

Measurement

16. In Joist and Plank the size of a shake shall be taken as the shortest distance between lines inclosing the shake and parallel to the wide faces of the piece.

BEAMS AND STRINGERS

Measurement

17. In Beams and Stringers the size of a shake shall be taken as the shortest distance between lines inclosing the shake and parallel to the wide faces of the piece.

POSTS AND TIMBERS

Measurement

18. In Posts and Timbers the size of a shake shall be measured between lines parallel to each pair of opposite faces, and the greater of these two distances shall be taken as its size.

MAXIMUM SHAKE AND CHECKS IN DENSE SELECT AND SELECT JOIST AND PLANK

19.

Green	*Width of End*	*Seasoned*
½″	2″	⅝″
¾″	3″	1″
1″	4″	1¼″

Maximum Shake and Checks in Dense Common and Common Joist and Plank

20.

Green	*Width of End*	*Seasoned*
¾″	2″	⅞″
1⅛″	3″	1¼″
1½″	4″	1¾″

Maximum Shake and Checks in Dense Select and Select Beams and Stringers

21.

Green	*Width of End*	*Seasoned*
1½″	6″	2″
2″	8″	2⅝″
2½″	10″	3¼″
3″	12″	4″
3½″	14″	4⅝″
4″	16″	5¼″
4½″	18″	6″
5″	20″	6⅝″
5½″	22″	7¼″
6″	24″	8″

Maximum Shake and Checks in Dense Common and Common Beams and Stringers

22.

Green	*Width of End*	*Seasoned*
2″	5″	2⅛″
2⅜″	6″	2⅝″
3⅛″	8″	3½″
4″	10″	4⅜″
4¾″	12″	5¼″
5½″	14″	6⅛″
6⅜″	16″	7″
7⅛″	18″	8″
8″	20″	8⅞″
8¾″	22″	9¾″
9½″	24″	10⅝″

Maximum Shake and Checks in Dense Select and Select Posts and Timbers

23.

Green	*Width of End*	*Seasoned*
2″	5″	2½″
2⅜″	6″	3″
3⅛″	8″	4″
4″	10″	5″
4¾″	12″	6″
5½″	14″	7″
6⅜″	16″	8″
7⅛″	18″	9″
8″	20″	10″
8¾″	22″	11″
9½″	24″	12″

MAXIMUM SHAKE AND CHECKS IN DENSE COMMON AND COMMON POSTS AND TIMBERS

24.

Green	*Width of End*	*Seasoned*
3″	6″	3½″
4″	8″	4¾″
5″	10″	6″
6″	12″	7⅛″
7″	14″	8⅜″
8″	16″	9½″
9″	18″	10¾″
10″	20″	12″
11″	22″	13⅛″
12″	24″	14⅜″

SLOPE OF GRAIN

ALL CLASSIFICATIONS

Measurement

25. Slope of Grain shall be measured over a distance which will assure the determination of the general slope of the grain, not influenced by short, local deviations.

In Bending

26. In a piece in bending, it is of greatest importance on the top and bottom faces. If meeting the limitation of a grade in these locations, it may be somewhat greater elsewhere.

DENSE SELECT AND SELECT JOIST AND PLANK

27. Slope of grain in center half of length shall not exceed 1 in 12.

DENSE COMMON AND COMMON JOIST AND PLANK

28. Slope of grain in center half of length shall not exceed 1 in 10.

DENSE SELECT AND SELECT BEAMS AND STRINGERS

29. Slope of grain in center half of length shall not exceed 1 in 15.

DENSE COMMON AND COMMON BEAMS AND STRINGERS

30. Slope of grain in center half of length shall not exceed 1 in 10.

DENSE SELECT AND SELECT POSTS AND TIMBERS

31. Slope of grain shall not exceed 1 in 10.

DENSE COMMON AND COMMON POSTS AND TIMBERS

32. Slope of grain shall not exceed 1 in 8.

WANE OR SQUARE EDGES

DENSE SELECT AND SELECT GRADE

Wane ⅛

33A. Wane is permitted, not exceeding ⅛ the width of any face.

SQUARE EDGES

Square Edges

33B. All edges must be square.

DENSE COMMON AND COMMON GRADE

Wane ¼

34A. Wane is permitted, not exceeding ¼ the width of any face.

SQUARE EDGES

Square Edges

34B. All edges must be square.

HEARTWOOD AND SAPWOOD

DURABILITY UNTREATED

Heartwood requirements to be specified as required from following:

HEARTWOOD PROVISIONS

Joist and Plank

35. Joist and Plank shall have not less than 85 per cent heart on the two faces, measured across the faces anywhere in the length of the piece.

Beams and Stringers

36. Beams and Stringers shall have not less than 85 per cent heart on each of the four faces, measured across the faces anywhere in the length of the piece.

Timbers 85 Per Cent

37A. These timbers shall have not less than 85 per cent heart on each of the four faces, measured across the face anywhere in the length of the piece.

Timbers, One Face All Heart, Others 85 Per Cent

37B. These timbers shall have all heart on one narrow face, the other narrow face and the two sides shall have not less than 85 per cent of heart, measured across the face or sides anywhere in the length of the piece.

Timbers, One Face All Heart, Others 75 Per Cent

37C. These timbers shall have all heart on one narrow face, the other narrow face and the two sides shall have not less than 75 per cent of heart, measured across the face or sides anywhere in the length of the piece.

FOR TREATMENT

Provision for sapwood for timber to be treated is covered by following:

SAPWOOD

Sapwood Not Restricted

38. There is no restriction as to sapwood for this material.

RATE OF GROWTH AND DENSITY

Close Grain

Douglas Fir of Select grade is to be selected for close grain.

Density

Southern Pine or Douglas Fir of Dense grades are to be selected for density.

CLOSE GRAINED DOUGLAS FIR

Close Grain

39. Douglas Fir shall be of close grain, averaging on either one end or the other not less than six nor more than twenty annual rings per inch measured over a three-inch portion of a radial line located as described below. Pieces averaging from five to six annual rings per inch shall be accepted as the equivalent of close grain if having one-third or more summerwood.

DENSE DOUGLAS FIR

Dense

40. Douglas Fir shall be dense, averaging on either one end or the other not less than six annual rings per inch and, in addition, one-third or more summerwood measured over a three-inch portion of a radial line located as described below. The contrast in color between summerwood and springwood shall be distinct. Coarse grained material excluded by this rule shall be accepted as dense if averaging one-half or more summerwood.

CLOSE GRAIN OR DENSITY

Radial Line Representative

41. The radial line shall be representative of the average growth on the cross-section. When the radial line specified is not representative, it shall be shifted sufficiently to present a fair average, but the distance from the pith to the beginning of the three-inch portion of the line in boxed heart pieces shall not be changed.

CLOSE GRAIN

Average on Two Radial Lines

42. In case of disagreement, two radial lines shall be chosen, and the number of rings shall be the average determined on these lines.

DENSITY

Average on Two Radial Lines

43. In case of disagreement, two radial lines shall be chosen, and the number of rings and percentage of summerwood shall be the average determined on these lines.

LOCATION OF RADIAL LINE IN DOUGLAS FIR

Sidecut Pieces

44a. In side cut pieces of Douglas Fir, the radial line shall be at a right angle to the annual rings and the center of the three-inch portion of the line shall be at the center of the end of the piece.

Boxed Heart Pieces

b. In boxed heart pieces the line shall run from the pith to the corner farthest from the pith. When the least dimension is six inches or less, the three-inch portion of the line shall begin at a distance of one inch from the pith. When the least dimension is more than six inches, the three-inch portion of the line shall begin at a distance from the pith equal to two inches less than one-half the least dimension of the piece.

c. If a three-inch portion of the radial line cannot be obtained, the measurement shall be made over as much of the three-inch portion as is available.

DENSE SOUTHERN PINE

Dense

45. Southern Pine shall be dense, averaging on either one end or the other not less than six annual rings per inch and, in addition, one-third or more summerwood measured over a three-inch portion of a radial line located as described below. The contrast in color between summerwood and springwood shall be sharp and the summerwood shall be dark in color, except in pieces having considerably above the minimum requirement for summerwood. Coarse grained material excluded by this rule shall be accepted as dense if averaging one-half or more summerwood.

Radial Line Representative

46. The radial line shall be representative of the average growth on the cross-section.

Average on Two Radial Lines

47. In case of disagreement, two radial lines shall be chosen, and the number of rings and percentage of summerwood shall be the average determined on these lines.

Location of Radial Line in Southern Pine

Boxed Heart Pieces

48a. In boxed heart pieces of Southern Pine, the measurement shall be made over the third, four and fifth inches from the pith along the radial line.

Pith, Not Present

b. In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy, the inspection shall be made over three inches on an approximate radial line beginning at the edges nearest the pith in timbers over three inches in thickness and on the second inch nearest to the pith in timbers three inches or less in thickness.

Pith Present, But Less Than Five-Inch Radial Line

c. In material containing the pith but not a five-inch radial line, which is less than two inches by eight inches in section or less than eight inches in width, that does not show over sixteen square inches on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a five-inch radial line, the inspection shall apply to the three inches farthest from the pith.

Douglas Fir or Southern Pine

Inspection for Density

49. In inspection for density, reasonable variation of opinion between inspectors must be recognized. In reinspection of a particular lot of timbers for density, for every three timbers accepted as having one-third or more summerwood, one of the remaining timbers shall be accepted if agreed upon as having between 30 and 33⅓ per cent summerwood.

STRUCTURAL GRADES AND REFERENCE CODE

Specifications are divided into sections with general numbers for reference.

Where alternate specifications are listed each has a capital letter added to the general number. For any material, appropriate choice must be made of such paragraphs.

Where several paragraphs occur under the general number and each is designated by small letters, all such paragraphs must be used in making a complete specification.

In cases where only a small number of sizes are ordered it is permissible to shorten the tables of maximum defects by copying sizes of defects corresponding only with the sizes being ordered.

Following is a complete list of numbered specifications, brief description of material and appropriate code numbers of sections required to write a complete specification for this material.

Index to Numbers of Specifications

GRADES	ADDITIONAL REQUIREMENTS						
	For use untreated					For treating	
	For durability Heartwood required			No Heartwood or Sapwood Provision		Sapwood not Restricted	
	One Face 100% Other 3 Faces 85%	All Faces 85%	One Face 100% Other 3 Faces 75%	Square Edge	Wane Permitted	Square Edge	Wane Permitted
	Square Edge						
Beams and Stringers							
Dense Select Douglas Fir or Southern Pine..	....	1	....	2	3	4	6
Select Douglas Fir..................	....	6	....	7	8	9	
Select Other softwood species except Southern Pine..............	....	11	....	12	13	14	
Dense Common Douglas Fir or Southern Pine..	....	16	....	17	18	19	20
Common All softwood species............	....	21	....	22	23	24	25
Joists and Planks							
Dense Select Douglas Fir or Southern Pine..	....	26	....	27	28	29	30
Select Douglas Fir..................	....	31	....	32	33	34	35
Select Other softwood species except Southern Pine..............	....	36	....	37	38	39	40
Dense Common Douglas Fir or Southern Pine..	....	41	....	42	43	44	45
Common All softwood species............	....	46	....	47	48	49	50
Posts and Timbers							
Dense Select Douglas Fir or Southern Pine..	76	51	81	52	53	54	55
Select Douglas Fir..................	77	56	82	57	58	59	60
Select Other softwood species except Southern Pine..............	78	61	83	62	63	64	65
Dense Common Douglas Fir or Southern Pine..	79	66	84	67	68	69	70
Common All softwood species............	80	71	85	72	73	74	75

CODED SPECIFICATIONS FOR STRUCTURAL GRADES

DENSE SELECT BEAMS AND STRINGERS

No. 1. Beams and Stringers, Douglas Fir or Southern Pine, Dense Select, 85 per cent heartwood, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B, 36; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 2. Beams and Stringers, Douglas Fir or Southern Pine, Dense Select, no heartwood or sapwood requirement, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 3. Beams and Stringers, Douglas Fir or Southern Pine, Dense Select, no hearwood or sapwood requirement, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33A; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 4. Beams and Stringers, Douglas Fir or Southern Pine, Dense Select, sapwood wanted for treatment, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 5. Beams and Stringers, Douglas Fir or Southern Pine, Dense Select, sapwood wanted for treatment, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33A, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

SELECT BEAMS AND STRINGERS

No. 6. Beams and Stringers, Douglas Fir, Select, 85 per cent heartwood, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B, 36, 39, 41, 42, 44 (a+b+c).

No. 7. Beams and Stringers, Douglas Fir, Select, no heartwood or sapwood requirement, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B, 39, 41, 42, 44 (a+b+c).

No. 8. Beams and Stringers, Douglas Fir, Select, no heartwood or sapwood requirement, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33A, 39, 41, 42, 44 (a+b+c).

No. 9. Beams and Stringers, Douglas Fir, Select, sapwood wanted for treatment, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B, 38, 39, 41, 42, 44 (a+b+c).

No. 10. Beams and Stringers, Douglas Fir, Select, sapwood wanted for treatment, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33A, 38, 39, 41, 42, 44 (a+b+c).

No. 11. Beams and Stringers, Select, 85 per cent heartwood, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B, 36.

No. 12. Beams and Stringers, Select, no heartwood or sapwood requirement, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B.

No. 13. Beams and Stringers, Select, no heartwood or sapwood requirement, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33A.

No. 14. Beams and Stringers, Select, sapwood wanted for treatment, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33B, 38.

No. 15. Beams and Stringers, Select, sapwood wanted for treatment, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 12 (a+b), 17, 21, 25, 26, 29, 33A, 38.

Dense Common Beams and Stringers

No. 16. Beams and Stringers, Douglas Fir or Southern Pine, Dense Common, 85 per cent heartwood, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34B, 36; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 17. Beams and Stringers, Douglas Fir or Southern Pine, Dense Common, no heartwood or sapwood requirement, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34B; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 18. Beams and Stringers, Douglas Fir or Southern Pine, Dense Common, no heartwood or sapwood requirement, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34A; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 19. Beams and Stringers, Douglas Fir or Southern Pine, Dense Common, sapwood wanted for treatment, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34B, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49

No. 20. Beams and Stringers, Douglas Fir or Southern Pine, Dense Common, sapwood wanted for treatment, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34A, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

COMMON BEAMS AND STRINGERS

No. 21. Beams and Stringers, Common, 85 per cent heartwood, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34B, 36.

No. 22. Beams and Stringers, Common, no heartwood or sapwood requirement, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34B.

No. 23. Beams and Stringers, Common, no heartwood or sapwood requirement, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34A.

No. 24. Beams and Stringers, Common, sapwood wanted for treatment, square edges.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34B, 38.

No. 25. Beams and Stringers, Common, sapwood wanted for treatment, wane permitted.
2A (surfaced) or 2B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 8 (a+b+c+d+e), 13 (a+b), 17, 22, 25, 26, 30, 34A, 38.

DENSE SELECT JOIST AND PLANK

No. 26. Joint and Plank, Douglas Fir or Southern Pine, Dense Select, 85 per cent heartwood, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B, 35; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 27. Joist and Plank, Douglas Fir or Southern Pine, Dense Select, no heartwood or sapwood requirement, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B; density. 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 28. Joist and Plank, Douglas Fir or Southern Pine, Dense Select, no heartwood or sapwood requirement, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33A; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 29. Joist and Plank, Douglas Fir or Southern Pine, Dense Select, sapwood wanted for treatment, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 30. Joist and Plank, Douglas Fir or Southern Pine, Dense Select, sapwood wanted for treatment, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33A, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

SELECT JOIST AND PLANK

No. 31. Joint and Plank, Douglas Fir, Select, 85 per cent heartwood, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B, 35, 39, 41, 42, 44 (a+b+c).

No. 32. Joist and Plank, Douglas Fir, Select, no heartwood or sapwood requirement, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B, 39, 41, 42, 44 (a+b+c).

No. 33. Joist and Plank, Douglas Fir, Select, no heartwood or sapwood requirement, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33A, 39, 41, 42, 44 (a+b+c).

No. 34. Joist and Plank, Douglas Fir, Select, sapwood wanted for treatment, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B, 38, 39, 41, 42, 44 (a+b+c).

No. 35. Joist and Plank, Douglas Fir, Select, sapwood wanted for treatment, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33A, 38, 39, 41, 42, 44 (a+b+c).

No. 36. Joist and Plank, Select, 85 per cent heartwood, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B, 35.

No. 37. Joist and Plank, Select, no heartwood or sapwood requirement, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B.

No. 38. Joist and Plank, Select, no heartwood or sapwood requirement, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33A.

No. 39. Joist and Plank, Select, sapwood wanted for treatment, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33B, 38.

No. 40. Joist and Plank, Select, sapwood wanted for treatment, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 10 (a+b+c), 16, 19, 25, 26, 27, 33A, 38.

DENSE COMMON JOIST AND PLANK

No. 41. Joist and Plank, Douglas Fir or Southern Pine, Dense Common, 85 per cent heartwood, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34B, 35; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 42. Joist and Plank, Douglas Fir or Southern Pine, Dense Common, no heartwood or sapwood requirement, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l); 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34B; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 43. Joint and Plank, Douglas Fir or Southern Pine, Dense Common, no heartwood or sapwood requirement, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34A; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 44. Joist and Plank, Douglas Fir or Southern Pine, Dense Common, sapwood wanted for treatment, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34B, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 45. Joist and Plank, Douglas Fir or Southern Pine, Dense Common, sapwood wanted for treatment, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34A, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

COMMON JOIST AND PLANK

No. 46. Joist and Plank, Common, 85 per cent heartwood, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34B, 35.

No. 47. Joist and Plank, Common, no heartwood or sapwood requirement, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34B.

No. 48. Joist and Plank, Common, no heartwood or sapwood requirement, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34A.

No. 49. Joist and Plank, Common, sapwood wanted for treatment, square edges.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34B, 38.

No. 50. Joist and Plank, Common, sapwood wanted for treatment, wane permitted.
1A (surfaced) or 1B (rough), 4 (surfaced), 5, 6 (a+b+c+d-+e+f+g+h+i+j+k+l), 7 (a+b+c+d), 11 (a+b+c), 16, 20, 25, 26, 28, 34A, 38.

Dense Select Posts and Timbers

No. 51. Posts and Timbers, Douglas Fir or Southern Pine, Dense Select, 85 per cent heartwood, square edges.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33B, 37A; density: 40, 41, 43, 44 (a + b + c), Douglas Fir, or 45, 46, 47, 48 (a + b + c), Southern Pine, 49.

No. 52. Posts and Timbers, Douglas Fir or Southern Pine, Dense Select, no heartwood or sapwood requirement, square edges.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33B; density: 40, 41, 43, 44 (a + b + c), Douglas Fir, or 45, 46, 47, 48 (a + b + c), Southern Pine, 49.

No. 53. Posts and Timbers, Douglas Fir or Southern Pine, Dense Select, no heartwood or sapwood requirement, wane permitted.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33A; density: 40, 41, 43, 44 (a + b + c), Douglas Fir, or 45, 46, 47, 48 (a + b + c), Southern Pine, 49.

No. 54. Posts and Timbers, Douglas Fir or Southern Pine, Dense Select, sapwood wanted for treatment, square edges.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33B, 38; density: 40, 41, 43, 44 (a + b + c), Douglas Fir, or 45, 46, 47, 48 (a + b + c), Southern Pine, 49.

No. 55. Posts and Timbers, Douglas Fir or Southern Pine, Dense Select, sapwood wanted for treatment, wane permitted.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33A, 38; density: 40, 41, 43, 44 (a + b + c), Douglas Fir, or 45, 46, 47, 48 (a + b + c), Southern Pine, 49.

Select Posts and Timbers

No. 56. Posts and Timbers, Douglas Fir, Select, 85 per cent heartwood, square edges.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33B, 37A, 39, 41, 42, 44 (a + b + c).

No. 57. Posts and Timbers, Douglas Fir, Select, no heartwood or sapwood requirement, square edges.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33B; 39, 41, 42, 44 (a + b + c).

No. 58. Posts and Timbers, Douglas Fir, Select, no heartwood or sapwood requirement, wane permitted.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33A, 39, 41, 42, 44 (a + b + c).

No. 59. Posts and Timbers, Douglas Fir, Select, sapwood wanted for treatment, square edges.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14, (a + b), 18, 23, 25, 31, 33B, 38, 39, 41, 42, 44 (a + b + c).

No. 60. Posts and Timbers, Douglas Fir, Select, sapwood wanted for treatment, wane permitted.

3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a + b + c + d + e + f + g + h + i + j + k + l), 9, 14 (a + b), 18, 23, 25, 31, 33B; 38, 39, 41, 42, 44 (a + b + c).

No. 61. Posts and Timbers, Select, 85 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14 (a+b), 18, 23, 25, 31, 33B, 37A.

No. 62. Posts and Timbers, Select, no heartwood or sapwood requirement, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33B.

No. 63. Posts and Timbers, Select, no heartwood or sapwood requirement, wane permitted.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33A.

No. 64. Posts and Timbers, Select, sapwood wanted for treatment, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33B, 38.

No. 65. Posts and Timbers, Select, sapwood wanted for treatment, wane permitted.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14 (a+b), 18, 23, 25, 31, 33A, 38.

DENSE COMMON POSTS AND TIMBERS

No. 66. Posts and Timbers, Douglas Fir or Southern Pine, Dense Common, 85 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B, 37A; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 67. Posts and Timbers, Douglas Fir or Southern Pine, Dense Common, no heartwood or sapwood requirement, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 68. Posts and Timbers, Douglas Fir or Southern Pine, Dense Common, no heartwood or sapwood requirement, wane permitted.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34A; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 69. Posts and Timbers, Douglas Fir or Southern Pine, Dense Common, sapwood wanted for treatment, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 70. Posts and Timbers, Douglas Fir or Southern Pine, Dense Common, sapwood wanted for treatment, wane permitted.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34A, 38; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

COMMON POSTS AND TIMBERS

No. 71. Posts and Timbers, Common, 85 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B, 37A.

No. 72. Posts and Timbers, Common, no heartwood or sapwood requirement, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B.

No. 73. Posts and Timbers, Common, no heartwood or sapwood requirement, wane permitted.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34A.

No. 74. Posts and Timbers, Common, sapwood wanted for treatment, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B, 38.

No. 75. Posts and Timbers, Common, sapwood wanted for treatment, wane permitted.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34A, 38.

SPECIAL POSTS AND TIMBERS

No. 76. Posts and Timbers, Douglas Fir or Southern Pine, Dense Select, one narrow face all heartwood, other narrow face and sides 85 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33B, 37B; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 77. Posts and Timbers, Douglas Fir, Select, one narrow face all heartwood, other narrow face and sides 85 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33B, 37B, 39, 41, 42, 44 (a+b+c).

No. 78. Posts and Timbers, Select, one narrow face all heartwood, other narrow face and sides 85 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33A, 37B.

No. 79. Posts and Timbers, Douglas Fir or Southern Pine, Dense Common, one narrow face all heartwood, other narrow face and sides 85 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B, 37B; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 80. Posts and Timbers Common, one narrow face all heartwood, other narrow face and sides 85 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B, 37B.

No. 81. Posts and Timbers, Douglas Fir or Southern Pine, Dense Select, one narrow face all heartwood, other narrow face and sides 75 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33B, 37C; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 82. Posts and Timbers Douglas Fir, Select, one narrow face all heartwood, other narrow face and sides 75 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33B, 37C, 39, 41, 42, 44 (a+b+c).

No. 83. Posts and Timbers, Select, one narrow face all heartwood, other narrow face and sides 75 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 14, (a+b), 18, 23, 25, 31, 33B, 37C.

No. 84. Posts and Timbers, Douglas Fir or Southern Pine, Dense Common, one narrow face all heartwood, other narrow face and sides 75 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B, 37C; density: 40, 41, 43, 44 (a+b+c), Douglas Fir, or 45, 46, 47, 48 (a+b+c), Southern Pine, 49.

No. 85. Posts and Timbers, Common, one narrow face all heartwood, other narrow face and sides 75 per cent heartwood, square edges.
3A (surfaced) or 3B (rough), 4 (surfaced), 5, 6 (a+b+c+d+e+f+g+h+i+j+k+l), 9, 15 (a+b), 18, 24, 25, 32, 34B, 37C.

EXAMPLES OF APPLICATION OF CODE

Three complete specifications are shown to illustrate the application of the code.

EXAMPLE NO. 1. SPECIFICATION NO. 1

Dense Select Beams and Stringers (Southern Pine) with Square Edges and Heartwood Requirement for Use Untreated, Rough

Timber Size Requirement

2B. Rough Structural Beams and Stringers shall be not smaller than the nominal sizes less ¼ inch for sizes 7 inches and less, and less ⅜ inch for sizes 8 inches and over.

Grade Requirements

5. This material shall contain only sound wood, free from any form of decay, incipient or advanced, including firm red heart, dote, and rot.

General

6a. No pieces of exceptionally light weight shall be permitted in any grade.

b. Shake shall be measured on the ends of a piece. Checks and splits shall be limited as provided for shakes. No checks or combinations of checks with shakes which would reduce the strength to a greater extent than the allowable shake shall be permitted.

c. Pitch pockets are ordinarily not defects in a structural grade. A large number, however, indicates a general lack of bond, and such a piece should be carefully examined for shakes.

d. Where wane is permitted there shall be no combination of wane and knots which would reduce the strength more than the maximum allowable knot.

e. Cluster knots and knots in groups are not permitted.

f. Knot holes and holes from other causes than knots shall be permitted as provided for knots.

g. The size of a knot shall be measured on the section of the knot appearing on the face under consideration.

h. Knot sizes specified shall be applied to spike knots as well as to round knots.

i. The faces of a piece of dimension or of a timber are the four longitudinal surfaces of the piece, sometimes further designated as "wide" faces or "narrow" faces.

j. In a piece of dimension or a timber graded for use in bending, wide faces shall be taken as vertical faces, and narrow faces as horizontal faces, unless otherwise noted.

k. When the faces of a piece of dimension or a timber are of equal width, Posts and Timber grades shall be used unless otherwise noted. When such a piece of dimension or such a timber is graded for use in bending, the best faces shall be taken as the horizontal faces and should be so marked.

l. The edges of a piece of dimension or of a timber are understood to be the narrower faces, and the sides the wider faces. For the locations of knots and other defects, however, the edges of a given face shall be taken to be the intersection of two adjacent faces, commonly called corners in the past.

KNOTS

BEAMS AND STRINGERS

8a. On wide or vertical faces of Beams and Stringers the smallest diameter of a knot shall be taken as its size.

b. On narrow or horizontal faces of Beams and Stringers the size of a knot shall be taken as its width between lines parallel to the edges of the piece.

c. Knots at edges of wide or vertical faces of Beams and Stringers are limited to the same size as on the adjacent narrow or horizontal faces, but the size is measured on the least diameter of the knot instead of on its width between lines parallel to the edges of the timber.

d. The size of knots on narrow or horizontal faces and at edges at wide or vertical faces of Beams and Stringers may increase proportionately from the size allowed in the middle third to twice that size at the ends of the piece.

e. The sizes of knots on wide or vertical faces of Beams and Stringers may increase proportionately from the size allowed at the edge to that allowed at the center line.

MAXIMUM KNOTS IN DENSE SELECT AND SELECT BEAMS AND STRINGERS

12a.

Narrow or horizontal face middle third of length	*Width of face*	*Center line of wide or vertical face*
1¼″	5″	1¼″
1½″	6″	1½″
1¾″	8″	2″
2″	10″	2½″
2⅛″	12″	3″
2¼″	14″	3¼″
2⅜″	16″	3⅜″
...	18″	3⅝″
...	20″	3⅞″
...	22″	4″
...	24″	4¼″

b. The sum of the diameters of all knots within the center half of the length of a Beam or Stringer on any face shall not exceed the width of the face on which they occur.

SHAKE AND CHECKS

17. In Beams and Stringers the size of a shake shall be taken as the shortest distance between lines inclosing the shake and parallel to the wide faces of the piece.

MAXIMUM SHAKE AND CHECKS IN DENSE SELECT AND SELECT BEAMS AND STRINGERS

21.

Green	*Width of end*	*Seasoned*
1½″	6″	2″
2″	8″	2⅝″
2½″	10″	3¼″
3″	12″	4″
3½″	14″	4⅝″
4″	16″	5¼″
4½″	18″	6″
5″	20″	6⅝″
5½″	22″	7¼″
6″	24″	8″

SLOPE OF GRAIN

25. Slope of Grain shall be measured over a distance which will assure the determination of the general slope of the grain, not influenced by short, local deviations.

26. In a piece in bending, it is of greatest importance on the top and bottom faces. If meeting the limitation of a grade in these locations, it may be somewhat greater elsewhere.

29. Slope of grain in center half of length shall not exceed 1 in 15.

SQUARE EDGES

33B. All edges must be square.

HEARTWOOD

36. Beams and Stringers shall have not less than 85 per cent heart on each of the four faces, measured across the faces anywhere in the length of the piece.

DENSITY

45. Southern Pine shall be dense, averaging on either one end or the other not less than six annual rings per inch and, in addition, one-third or more summerwood measured over a three-inch portion of a radial line located as described below. The contrast in color between summerwood and springwood shall be sharp and the summerwood shall be dark in color, except in pieces having considerably above the minimum requirement for summerwood. Coarse grained material excluded by this rule shall be accepted as dense if averaging one-half or more summerwood.

46. The radial line shall be representative of the average growth on the cross-section.

47. In case of disagreement, two radial lines shall be chosen, and the number of rings and percentage of summerwood shall be the average determined on these lines.

48a. In boxed heart pieces of Southern Pine, the measurement shall be made over the third, fourth and fifth inches from the pith along the radial line.

b. In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy, the inspection shall be made over three inches on an approximate radial line beginning at the edge nearest the pith in timbers over three inches in thickness and on the second inch nearest to the pith in timbers three inches or less in thickness.

c. In material containing the pith but not a five-inch radial line, which is less than two inches by eight inches in section or less than eight inches in width, that does not show over sixteen square inches on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a five-inch radial line, the inspection shall apply to the three inches farthest from the pith.

49. In inspection for density, reasonable variation of opinion between inspectors must be recognized. In reinspection of a particular lot of timbers for density, for every three timbers accepted as having one-third or more summerwood, one of the remaining timbers shall be accepted if agreed upon as having between 30 and 33⅓ per cent summerwood.

EXAMPLE NO. 2. SPECIFICATION NO. 60

SELECT POSTS AND TIMBERS (DOUGLAS FIR) WITH WANE PERMITTED AND SAPWOOD WANTED FOR TREATMENT, SURFACED FOUR SIDES

TIMBER SIZE REQUIREMENT

3A. Structural Posts and Timbers shall be when surfaced S1S, S1E, S2S or S4S not smaller than the nominal size less ⅜ inch for sizes 7 inches and less, and less ½ inch for sizes 8 inches and over.

4. The dressed dimensions specified in paragraph 3A shall be minimum dimensions when measured green.

GRADE REQUIREMENTS

5. This material shall contain only sound wood, free from any form of decay, incipient or advanced, including firm red heart, dote, and rot.

GENERAL

6a. No pieces of exceptionally light weight shall be permitted in any grade.

b. Shake shall be measured on the ends of a piece. Checks and splits shall be limited as provided for shakes. No checks or combinations of checks with shakes which would reduce the strength to a greater extent than the allowable shake shall be permitted.

c. Pitch pockets are ordinarily not defects in a structural grade. A large number, however, indicates a general lack of bond, and such a piece should be carefully examined for shakes.

d. Where wane is permitted there shall be no combination of wane and knots which would reduce the strength more than the maximum allowable knot.

e. Cluster knots and knots in groups are not permitted.

f. Knot holes and holes from other causes than knots shall be permitted as provided for knots.

g. The size of a knot shall be measured on the section of the knot appearing on the face under consideration.

h. Knot sizes specified shall be applied to spike knots as well as to round knots.

i. The faces of a piece of dimension or of a timber are the four longitudinal surfaces of the piece, sometimes further designated as "wide" faces or "narrow" faces.

j. In a piece of dimension or a timber graded for use in bending, wide faces shall be taken as vertical faces, and narrow faces as horizontal faces, unless otherwise noted.

k. When the faces of a piece of dimension or a timber are of equal width, Post and Timber grades shall be used unless otherwise noted. When such a piece of dimension or such a timber is graded for use in bending, the best faces shall be taken as the horizontal faces and should be so marked.

l. The edges of a piece of dimension or of a timber are understood to be the narrower faces, and the sides the wider faces. For the locations of knots and other defects, however, the edges of a given face shall be taken to be the intersection of two adjacent faces, commonly called corners in the past.

KNOTS

9. In Posts and Timbers, the size of a knot shall be measured on the mean or average diameter. The mean or average diameter of a knot shall be taken as the average of its maximum and minimum diameters. The average diameter of a spike knot shall be taken as the average of its length and its maximum width.

MAXIMUM KNOTS* IN DENSE SELECT AND SELECT POSTS AND TIMBERS

14a.

Width of face	*Knots*
6"	1½"
8"	2"
10"	2½"
12"	3"
14"	3¼"
16"	3⅜"
18"	3⅝"
20"	3⅞"
22"	4"
24"	4¼"

*On faces less than 6", knots shall not exceed ¼ width of face.

b. The sum of the diameters of all knots in any 6 inches of the length of a Post or Timber shall not exceed twice the size of the maximum knot allowable, nor shall there be two of maximum allowable knots in same 6 inches of length on any one face.

SHAKE AND CHECKS

18. In Posts and Timbers the size of a shake shall be measured between lines parallel to each pair of opposite faces, and the greater of these two distances shall be taken as its size.

MAXIMUM SHAKE AND CHECKS IN DENSE SELECT AND SELECT POSTS AND TIMBERS

23.

Green	*Width of end*	*Seasoned*
2"	5"	2½"
2⅜"	6"	3"
3⅛"	8"	4"
4"	10"	5"
4¾"	12"	6"
5½"	14"	7"
6⅜"	16"	8"
7⅛"	18"	9"
8"	20"	10"
8¾"	22"	11"
9½"	24"	12"

SLOPE OF GRAIN

25. Slope of Grain shall be measured over a distance which will assure the determination of the general slope of the grain, not influenced by short, local deviations.

31. Slope of grain shall not exceed 1 in 10.

WANE

33A. Wane is permitted, not exceeding ⅛ the width of any face.

SAPWOOD

38. There is no restriction as to sapwood for this material.

RATE OF GROWTH

39. Douglas Fir shall be of close grain, averaging on either one end or the other not less than six nor more than twenty annual rings per inch

measured over a three-inch portion of a radial line located as described below. Pieces averaging from five to six annual rings per inch shall be accepted as the equivalent of close grain if having one-third or more summerwood.

41. The radial line shall be representative of the average growth on the cross-section. When the radial line specified is not representative, it shall be shifted sufficiently to present a fair average, but the distance from the pith to the beginning of the three-inch portion of the line in boxed heart pieces shall not be changed.

42. In case of disagreement, two radial lines shall be chosen, and the number of rings shall be the average determined on these lines.

44a. In side cut pieces of Douglas Fir, the radial line shall be at a right angle to the annual rings and the center of the three-inch portion of the line shall be at the center of the end of the piece.

b. In boxed heart pieces the line shall run from the pith to the corner farthest from the pith. When the least dimension is six inches or less, the three-inch portion of the line shall begin at a distance of one inch from the pith. When the least dimension is more than six inches, the three-inch portion of the line shall begin at a distance from the pith equal to two inches less than one-half the least dimension of the piece.

c. If a three-inch portion of the radial line cannot be obtained the measurement shall be made over as much of the three-inch portion as is available.

EXAMPLE NO. 3. SPECIFICATION NO. 48

Common Joist and Plank with Wane Permissibility and no Heartwood or Sapwood Requirement, Surfaced S1S, S1E

Timber Size Requirement

1A. Structural Joist and Plank shall be when surfaced S1S or S2S not thinner than the nominal dimension less ⅜ inch and when surfaced S1E or S2E not narrower than the nominal width less ⅜ inch for sizes 2 to 7 inches, inclusive, and less ½ inch for sizes 8 inches and wider.

4. The dressed dimensions specified in paragraph 1A shall be minimum dimensions when measured green.

Grade Requirements

5. This material shall contain only sound wood, free from any form of decay, incipient or advanced, including firm red heart, dote and rot.

General

6a. No pieces of exceptionally light weight shall be permitted in any grade.

b. Shake shall be measured on the ends of a piece. Checks and splits shall be limited as provided for shakes. No checks or combination of checks with shakes which would reduce the strength to a greater extent than the allowable shake shall be permitted.

c. Pitch pockets are ordinarily not defects in a structural grade. A large number, however, indicates a general lack of bond, and such a piece should be carefully examined for shakes.

d. Where wane is permitted there shall be no combination of wane and knots which would reduce the strength more than the maximum allowable knot.

e. Cluster knots and knots in groups are not permitted.

f. Knot holes and holes from other causes than knots shall be permitted as provided for knots.

g. The size of a knot shall be measured on the section of the knot appearing on the face under consideration.

h. Knot sizes specified shall be applied to spike knots as well as to round knots.

i. The faces of a piece of dimension or of a timber are the four longitudinal surfaces of the piece, sometimes further designated as "wide" faces or "narrow" faces.

j. In a piece of dimension or a timber graded for use in bending, wide faces shall be taken as vertical faces, and narrow faces as horizontal faces, unless otherwise noted.

k. When the faces of a piece of dimension or a timber are of equal width, Posts and Timber grades shall be used unless otherwise noted. When such a piece of dimension or such a timber is graded for use in bending, the best faces shall be taken as the horizontal faces and should be so marked.

l. The edges of a piece of dimension or of a timber are understood to be the narrower faces, and the sides the wider faces. For the locations of knots and other defects, however, the edges of a given face shall be taken to be the intersection of two adjacent faces, commonly called corners in the past.

KNOTS

7a. On wide faces of Joist and Plank, the size of a knot shall be measured on the mean or average diameter. The mean or average diameter of a knot shall be taken as the average of its maximum and minimum diameters. The average diameter of a spike knot shall be taken as the average of its length and its maximum width.

b. On narrow faces of Joist and Plank, the size of a knot shall be taken as its width between lines parallel to the edges of the piece.

c. The size of knots on narrow faces and at edges of wide faces of Joist and Plank may increase proportionately from the size allowed in the middle third to twice that size at the ends of the piece.

d. The size of knots on wide faces of Joist and Plank may increase proportionately from the size allowed at the edge to that allowed at the center line.

Maximum Knots in Dense Common and Common Joist and Plank
Knots on Wide Faces

11a.

At edges, middle third of length	Width of face	On center line on face
1"	4"	1¾"
1½"	6"	2½"
2"	8"	3⅜"
2½"	10"	4¼"
3"	12"	5⅛"
3¼"	14"	5⅝"
3⅜"	16"	6"

b. Knots on Narrow Faces of Boxed Heart Pieces

Thickness of piece	Middle third of length
2"	⅞"
3"	1¼"
4"	1¾"

c. The sum of the diameters of all knots within the center half of the length of a Joist or Plank on any face shall not exceed two times the width of the face on which they occur.

Shake and Checks

16. In Joist and Plank the size of a shake shall be taken as the shortest distance between lines inclosing the shake and parallel to the wide faces of the piece.

Maximum Shake and Checks in Dense Common and Common Joist and Plank

20.

Green	Width of end	Seasoned
¾"	2"	⅞"
1⅛"	3"	1¼"
1½"	4"	1¾"

Slope of Grain

25. Slope of Grain shall be measured over a distance which will assure the determination of the general slope of the grain, not influenced by short, local deviations.

26. In a piece in bending, it is of greatest importance on the top and bottom faces. If meeting the limitation of a grade in these locations, it may be somewhat greater elsewhere.

28. Slope of grain in center half of length shall not exceed 1 in 10.

Wane

34A. Wane is permitted, not exceeding ¼ the width of any face.

NOTES ON WORKING STRESSES FOR STRUCTURAL GRADES OF AMERICAN LUMBER STANDARDS

Factors in Determination of Working Stresses

1. Many factors enter into the determination of working stresses. It is practically impossible to make a sufficient number of tests on large specimens of each species, containing the various defects of the species and in their various combinations, to determine working stresses in this way. It has been found, however, that similar defects have practically the same effect in all species.

Basis of Working Stresses

2. Working stresses are based on the strength of green, clear wood, increase in strength through drying being largely offset by development of defects during the drying, and are varied for conditions of exposure in properties affected by this factor.

Varying Factors

3. It is not sufficient, though, to apply an arbitrary factor of safety to test results on small clear pieces in all species in order to determine nominal working stresses for the clear wood of large sizes, to which defect-effect factors can be applied to determine working stresses for grades containing defects, nor to apply factors of safety to average values alone, but consideration must be given to minimum strengths as well as average, to the tendency of a species to run characteristically high or low in grade, to effect of length of time under load on the species, to effect of character of loading, and to conditions of exposure and susceptibility to them.

Variation in Species

4. These factors and characteristics sometimes dictate quite a variation in the relative status of species, as to whether small clear sizes are the basis for comparison, or structural sizes. One species may run characteristically lower than another in small, clear, values, while running characteristically higher in strength in structural sizes of equivalent character.

Determination of Basic Values

5. Determination of basic clear grade values for reduction to working stresses for grades containing defects, therefore, involves consideration of many factors in the light of experience and judgment, rather than the arbitrary application of factors of safety to test results on small clear pieces.

Basis of Working Stresses

6. It is on this basis that the working stresses recommended by the Forest Products Laboratory, U.S. Forest Service, for structural grades complying with Basic Provisions for Structural Material of American Lumber Standards have been determined, and they can be depended on to assure

that the low line piece of a grade will sustain safely the working stresses of the grade. In Beam and Stringer, and Posts and Timber grades, stresses are given only for the species commonly cut to those sizes. Stresses for other species can be obtained from the Forest Products Laboratory, Madison, Wisconsin.

Properties Requiring Working Stresses

7. Properties for which working stresses are required are: Extreme fiber in bending, horizontal shear, compression parallel to grain, compression perpendicular to grain, and modulus of elasticity.

Factors Requiring Variation in Working Stresses

8. In some of these properties, working stresses are governed by conditions of exposure; in other properties they are not. In some properties, working stresses are affected by grade, as fixed by limitation on size and location of knots, extent of shake and checks, and extent of slope of grain. In dimension sizes, continuously dry, higher stresses are allowed in extreme fiber in bending than are recommended for larger sizes with equal defects. In Douglas fir and southern pine, working stresses in some properties are increased for requirement of percentage of summerwood, and in Douglas fir, for limitation on rate of growth.

Working Stresses Varied

9. Working stresses for extreme fiber in bending are varied with extent of exposure, with size and position of knots, with slope of grain, and with size of piece; in horizontal shear, they are varied with extent of shake and checks; in compression parallel to grain, with exposure, and with size and location of knots, and slope of grain; in compression perpendicular to grain, with exposure.

Working Stresses Not Varied

10. Working stresses in horizontal shear are not varied with extent of exposure, nor with size of piece; in compression parallel to grain they are not varied with size; in compression perpendicular to grain, they are not varied with grade or size; in modulus of elasticity, they are taken as the same under all conditions.

Close Grain and Density

11. In Douglas fir and southern pine, working stresses in extreme fiber in bending, horizontal shear, compression parallel to grain and compression perpendicular to grain, may be increased $1/6$ for dense material, over material not so selected. Values in Douglas fir may be increased $1/15$ for close grain in extreme fiber in bending, compression parallel to grain and compression perpendicular to grain. Values in horizontal shear are not increased for close grain. Modulus of elasticity is not varied with density or rate of growth.

Variations in Working Stresses

12.

Property	*Governing Defects*	*Conditions of Exposure*	*Grade*	*Size of Piece*	*Rate of Growth*	*Density*
Extreme Fiber in Bending	Knots and Slope of Grain	x	x	x*	x	x
Horizontal Shear	Shake and Checks	–	x	–	–	x
Compression Parallel	Knots and Slope of Grain	x	x	–	x	x
Compression Perpendicular		x	–	–	x	x
Modulus of Elasticity		–	–	–	–	–

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*Dry location only.
xVaries with.
–Does not vary with.

Dry Dimension

13. In dimension sizes four inches and less in thickness, the development of defects during seasoning does not offset the increase in strength from drying as much as in larger sizes, and in these sizes used in dry locations, working stresses in extreme fiber in bending are increased proportionately from equal values with timbers, and dimension not continuously dry, in a grade having 50 per cent of the strength of clear wood, to values 25 per cent greater in clear wood.

Minimum Strength Value

14. Structural grades are developed to assure minimum strength values. The defects permitted in the Common Structural grades provide material having not less than 60 per cent of the strength of green clear wood, and in the Select Structural grades of 75 per cent, although in Douglas fir the stresses recommended in compression and in extreme fiber in bending are 80 per cent of green clear wood strength on account of provision of close grain.

Exposure

15. Working values are given for three conditions of exposure during use: (a) Continuously dry, (b) Occasionally wet but quickly dried, (c) More or less continuously damp or wet. Judgment should be exercised as to the conditions of exposure which should be assumed in a particular case.

Continuously Dry

(a) Continuously dry contemplates use in interior or protected construction not subject to conditions of excessive dampness or high humidity.

Occasionally Wet

(b) Occasionally wet but quickly dried assumes use in such exterior structures as bridges, trestles, grandstands or bleachers, and exposed frame work of open sheds.

Usually Wet

(c) More or less continuously damp or wet would apply to material exposed to waves or tidewater, or in contact with earth, or used in a building in portions that would be more or less continuously wet.

Impact

16. Working values may be used without allowance for impact up to impact of 100 per cent of loads figured. The ability of timbers to support loads is very dependent on the duration of the stress. Tests have demonstrated that the load required to break timbers in several years is about $\frac{9}{16}$ of that required to break them as in ordinary laboratory tests. When the time is shortened still further, as in impact loading, the load required to break a timber is correspondingly increased. Approximately, this increase is 10 per cent, when the time is reduced to $\frac{1}{10}$ of the previous time.

Maximum Horizontal Shear

17. Working values for horizontal shear are maximum values. The maximum unit horizontal shear at any point in a beam is $\frac{3}{2}$ of the average unit shear obtained by dividing the total shear at that point by the area of the cross-section. To get the total safe shearing stress at any cross-section, the area of the cross-section should be multiplied by $\frac{2}{3}$ the maximum allowable horizontal shear. To obtain the required area to carry any given shear, the total shear should be divided by $\frac{2}{3}$ the maximum allowable unit shear.

Analysis for Shear Stress

18. Recognition of all loads in designing for loads concentrated near a support, or for moving loads, gives a calculated shearing stress higher than is actually developed.

Concentrated Loads

19. For concentrated loadings, in calculating the shear at one end of a beam, the loads between that end and the nearer quarter point, or between that end and a point distant three times the depth of the beam from it, whichever would be the lesser distance from the support, may be considered as acting at that point.

Moving Loads

20. For moving loads, as on highway bridges or railway stringers, in computing the shear at one end it is safe to ignore the wheel loads between that end and the nearer quarter point, or between that end and a point three times the depth of the beam or stringer from it, whichever would be the lesser distance from the support, when the balance of the span is assumed to be loaded so as to give a maximum shear stress.

Shear Stresses for Joint Details

21. Shear stresses for joint details may be taken as 50 per cent greater than the values for horizontal shear given in the table.

Permanent Set

22. Timber constantly yields under continued loading, acquiring a permanent set. This set with a fully loaded beam is about equal to the deflection using the modulus of elasticity as given in the tables. In order to minimize the results of sag, it is advisable to use values one-half those given in the tables.

Compression in Short Columns

23. The working stresses for compression parallel to grain are for use on posts, struts, etc., with unsupported length not greater than ten times their least dimension. They are also for use in end bearing on compression members, as a short column or strut is more likely to fail at the end than at any other point in its length, and the variations in moisture content are greater at that point.

Compression in Medium Length Columns

24. For columns of intermediate length, the Forest Products Laboratory finds that a fourth-power parabola, tangent to the Euler curve, is a conservative representation of the law controlling the strength. That is, from the short block to the long column in which the strength is dependent on stiffness, there is a falling off in ultimate strength which follows a smooth curve, very flat at first but curving sharply to become tangent to the Euler curve, at two-thirds of the ultimate crushing strength.

Formula

25. For columns from $\frac{P}{A} = S$ to $\frac{P}{A} = \frac{2}{3}S$

$$\frac{P}{A} = S\left[1 - \frac{1}{3}\left(\frac{l}{Kd}\right)^4\right]$$

where P = Total load in pounds.
A = Area in square inches.
$\frac{P}{A}$ = Unit compressive stress.
S = Safe stress in compression parallel to grain for short columns.
l = Unsupported length in inches.
d = Least dimension in inches.
E = Modulus of elasticity.
K = The $\frac{l}{d}$ at the point of tangency of the parabolic and Euler curves, at which $\frac{P}{A} = \frac{2}{3}S$. The value of K for any species and grade is $\frac{\pi}{2}\sqrt{\frac{E}{6S}}$

Influence of Defects

26. The influence of defects on the compressive strength of columns of constant cross-section decreases as the length increases. When $\frac{l}{d}$ equals the value of K for the species and grade, defects such as are allowable in the grade have little influence on the strength as a column. Beyond this length the investigation of the strength of columns by the Laboratory indicated that the Euler formula is quite accurate for long wood columns with pin-end connections and that the maximum load is dependent upon stiffness. In such columns, a factor of safety of 3 should be applied to values of modulus of elasticity in order to obtain safe loading.

Square-end and Pin-end Columns

27. The Laboratory does not, with the present data and under ordinary conditions, find justification for increasing the stresses on square-end columns over those for carefully centered pin-end columns. Tests to determine the influence of end conditions are still being made and it is probable that under special conditions higher stresses can be used.

Long Columns

28. For long columns, including factor of safety of 3 =

$$\frac{P}{A} = \frac{\pi^2}{36} \frac{E}{\left(\frac{l}{d}\right)^2}$$

Maximum Length

29. Columns should be limited in slenderness to $\frac{l}{d} = 50$.

Small Struts

30. Post and Timber grades may be applied to material smaller than 6″ by 6″ by limiting the size of knots to the proportion of width of face permitted on a 6″ face.

Direct Tension

31. For direct tension the same values as for extreme fiber stress in bending may be used. Straight grained wood has greater resistance to tension than to any other kind of stress. It has been found, however, practically impossible to design joints that will develop anywhere near the full tensile strength.

Joists and Beams in Direct Tension

32. Grades of Joists or Beams may be used for members in direct tension, as in bottom chords of trusses, increase in size of defects towards

ends being permissible because of the gradual application of stresses through splice plates or end connections.

Joist and Plank—Vertical or Horizontal

33. The provisions of the Joist and Plank grades are such that material graded on them may be used on edge as joist or rafters, or flat, as scaffold plank or factory flooring and working stresses for these grades may be applied to such material used with wide faces either vertical or horizontal. Joist and Plank grades apply to material not thicker than four inches. Material thicker than four inches, for use in bending, should be graded on Beam and Stringer grades. In such material with loads applied to the wide face, the knot limitations for this face are those for the narrow face as given in the rules.

Working Stresses in Timbers Nearly Square

34. Material to be used for such purposes as caps, bridge ties, etc., where strength in bending is a factor, should be specified in Beam and Stringer grades, although of shape more commonly considerd as of timber grades, as the method of measuring knots in Post and Timber grades makes it impracticable to assign bending stresses to them. Caps and bridge ties are often square or have horizontal faces wider than the vertical faces, in contrast to Beam and Stringers, in which the narrow faces are horizontal faces and the wide faces are vertical, and care should be exercised that knot limitations are applied to the proper faces.

Material with Varying Bending Moment

35. In material subject to varying bending moments, such as full-length sills of wood under-framed cars, it should be specified that defects throughout the length be limited as in the center third of Beams and Stringers.

Two-Span Stringers

36. In railway stringers of two-span length, it should be specified that defects throughout the center two-thirds be limited as in the center third of a single-span stringer, for the maximum moment will be over the center support and although the full positive moment would not be developed in either as long as there was resistance to negative moment over the center support, there might be circumstances in which full positive moment of resistance at the centers of the two spans would be desirable.

Round Timbers

37. The strength of timbers and posts in round form is greater than would be expected from the ordinary engineering formulas. The strength, stiffness and shearing value in bending of round timbers of any species may be assumed to be identical with that of square timbers of the same grade and cross-sectional area. Tapered timbers should be assumed as of uniform

diameter, the point of measurement being one-third the span from the small end, but the diameter should not be assumed to be more than one and one-half times the end diameter.

Round Posts

38. The strength of round columns may be considered the same as that of square columns of the same cross-sectional area. In long tapered columns the strength may be assumed as identical with that of a square column of the same length, and of cross-sectional area equal to that of the round timber measured at a point one-third its length from the small end. The stress at the small end must not exceed the allowable stress for short columns.

Studies in Strength of Round Timbers

39. Detailed studies on the strength of timber in round form are available in Reports 180 and 181 of the National Advisory Committee for Aeronautics on "The Influence of the Form of a Wooden Beam on Its Stiffness and Strength."

FACTORS OF SAFETY

Elastic Limit and Breaking Strength

40. In determining working stresses, the Forest Products Laboratory has considered both elastic limit and breaking strength. Elastic limit, however, is more variable and less definite than ultimate strength, and the latter is taken as the more dependable basis for the determination of safe working stresses.

Factor of Safety

41. The factor of safety at a given working stress varies materially with the duration of the stress. At the recommended working stresses, the average timber in buildings has a factor of safety of 6 on impact loadings,* 4 under five-minute loads and 2¼ under long-time loading, with a minimum factor of safety of 2 on 75 per cent of the pieces under long-time loading, while about one piece in 100, of very light weight and with maximum defects for the grade, would be expected to break at 1½ times the recommended stress under loading of approximately 10 years duration. The factor of safety on new timbers in bridge work is about ⅐ greater than the above values.

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*If impact stresses are neglected when less than 100 per cent of the live load producing them, the factor of safety for such loads would be reduced from 6 to a minimum of 3.

WORKING STRESSES

Pounds per Square Inch

FOR MATERIAL COMPLYING WITH BASIC PROVISIONS FOR STRUCTURAL GRADES OF AMERICAN LUMBER STANDARDS

JOIST AND PLANK AND BEAMS AND STRINGERS

CONTINUOUSLY DRY

SELECT GRADE

Species	*Extreme Fiber in Bending*	*Compression Perpendicular to Grain*	*Maximum Horizontal Shear*	*Modulus of Elasticity*
Cedar, western red	900	200	80	1,000,000
northern and southern white	750	175	70	800,000
Port Orford	1100	250	90	1,200,000
Alaska	1100	250	90	1,200,000
Cypress, southern	1300	350	100	1,200,000
Douglas fir, Coast Region	1600	345	90	1,600,000
dense	1750	380	105	1,600,000
Rocky Mountain Region	1100	275	85	1,200,000
Fir, balsam	900	150	70	1,000,000
golden, noble, silver, white	1100	300	70	1,100,000
Hemlock, West Coast	1300	300	75	1,400,000
eastern	1100	300	70	1,100,000
Larch, western	1200	325	100	1,300,000
Pine, southern dense	1750	380	128	1,600,000
California, Idaho and Northern white, Pondosa and sugar	900	250	85	1,000,000
Norway	1100	300	85	1,200,000
Redwood	1200	250	70	1,200,000
Spruce, red, white, Sitka	1100	250	85	1,200,000
Englemann	750	175	70	800,000
Tamarack, eastern	1200	300	95	1,300,000

COMMON GRADE

Species	*Extreme Fiber in Bending*	*Compression Perpendicular to Grain*	*Maximum Horizontal Shear*	*Modulus of Elasticity*
Cedar, western red	720	200	64	1,000,000
northern and southern white	600	175	56	800,000
Port Orford	880	250	72	1,200,000
Alaska	880	250	72	1,200,000
Cypress, southern	1040	350	80	1,200,000
Douglas fir, Coast Region	1200	325	72	1,600,000
dense	1400	380	84	1,600,000
Rocky Mountain Region	880	275	68	1,200,000
Fir, balsam	720	150	56	1,000,000
golden, noble, silver, white	880	300	56	1,100,000
Hemlock, West Coast	1040	300	60	1,400,000
eastern	880	300	56	1,100,000
Larch, western	960	325	80	1,300,000
Pine, southern	1200	325	88	1,600,000
dense	1400	380	103	1,600,000
California, Idaho and northern white, Pondosa and sugar	720	250	68	1,000,000
Norway	880	300	68	1,200,000
Redwood	960	250	56	1,200,000
Spruce, red, white, Sitka	880	250	68	1,200,000
Englemann	600	175	56	800,000
Tamarack, eastern	960	300	76	1,300,000

NOTE.—Values are those recommended by Forest Products Laboratory.

WORKING STRESSES

Pounds per Square Inch

For Material Complying with Basic Provisions for Structural Grades of American Lumber Standards

JOIST AND PLANK AND BEAMS AND STRINGERS

Occasionally Wet But Quickly Dried

Select Grade

	Extreme Fiber in Bending		*Compression*		
	4" and Thinner	*5" and Thicker*	*Perpendicular to Grain*	*Maximum Horizontal Shear*	*Modulus of Elasticity*
Cedar, western red	710	800	150	80	1,000,000
northern and southern white	580	....	140	70	800,000
Port Orford	890	1000	200	90	1,200,000
Alaska	890	....	200	90	1,200,000
Cypress, southern	980	....	250	100	1,200,000
Douglas fir,					
Coast Region	1240	1385	240	90	1,600,000
dense	1370	1515	265	105	1,600,000
Rocky Mtn. Region	800	900	225	85	1,200,000
Fir, balsam	670	....	125	70	1,000,000
golden, noble, silver, white	800	....	225	70	1,100,000
Hemlock, West Coast	980	1100	225	75	1,400,000
eastern	800	....	225	70	1,100,000
Larch, western	980	1100	225	100	1,300,000
Pine, southern, dense	1370	1515	265	128	1,600,000
California, Idaho and northern white, Pondosa and sugar	710	....	150	85	1,000,000
Norway	890	....	175	85	1,200,000
Redwood	890	1000	150	70	1,200,000
Spruce, red, white, Sitka	800	900	150	85	1,200,000
Englemann	580	....	140	70	800,000
Tamarack, eastern	980	....	225	95	1,300,000

Common Grade

	Extreme Fiber in Bending		*Compression*		
	4" and Thinner	*5" and Thicker*	*Perpendicular to Grain*	*Maximum Horizontal Shear*	*Modulus of Elasticity*
Cedar, western red	600	640	150	64	1,000,000
northern and southern white	490	....	140	56	800,000
Port Orford	760	800	200	72	1,200,000
Alaska	760	....	200	72	1,200,000
Cypress, southern	830	....	250	80	1,200,000
Douglas fir,					
Coast Region	980	1040	225	72	1,600,000
dense	1145	1210	265	84	1,600,000
Rocky Mtn. Region	680	720	225	68	1,200,000
Fir, balsam	570	....	125	56	1,000,000
golden, noble, silver, white	680	....	225	56	1,100,000
Hemlock, West Coast	830	880	225	60	1,400,000
eastern	680	....	225	56	1,100,000
Larch, western	830	880	225	80	1,300,000

Pine, southern	980	1040	225	88	1,600,000
dense	1145	1210	265	103	1,600,000
California, Idaho and northern white, Pondosa and sugar	600	....	150	68	1,000,000
Norway	760	....	175	68	1,200,000
Redwood	760	800	150	56	1,200,000
Spruce, red, white, Sitka	680	720	150	68	1,200,000
Englemann	490	....	140	56	800,000
Tamarack, eastern	830	....	225	76	1,300,000

NOTE.—Values are those recommended by Forest Products Laboratory.

WORKING STRESSES

Pounds per Square Inch

FOR MATERIAL COMPLYING WITH BASIC PROVISIONS FOR STRUCTURAL GRADES OF AMERICAN LUMBER STANDARDS

JOIST AND PLANK AND BEAMS AND STRINGERS

MORE OR LESS CONTINUOUSLY DAMP OR WET

SELECT GRADE

Species	*Extreme Fiber in Bending*		*Compression Perpendicular to Grain*	*Maximum Horizontal Shear*	*Modulus of Elasticity*
	4″ and Thinner	*5″ and Thicker*			
Cedar, western red	670	750	125	80	1,000,000
northern and southern white	530	....	100	70	800,000
Port Orford	800	900	150	90	1,200,000
Alaska	800	....	150	90	1,200,000
Cypress, southern	800	....	225	100	1,200,000
Douglas fir,					
Coast Region	950	1065	215	90	1,600,000
dense	1050	1165	235	105	1,600,000
Rocky Mtn. Region	620	700	200	85	1,200,000
Fir, balsam	530	....	100	70	1,000,000
golden, noble, silver, white	710	....	200	70	1,100,000
Hemlock, West Coast	800	900	200	75	1,400,000
eastern	710	....	200	70	1,100,000
Larch, Western	800	900	200	100	1,300,000
Pine, southern, dense	1050	1165	235	128	1,600,000
California, Idaho and northern white, Pondosa and sugar	670	....	125	85	1,000,000
Norway	710	....	150	85	1,200,000
Redwood	710	800	125	70	1,200,000
Spruce, red, white, Sitka	710	800	125	85	1,200,000
Englemann	440	....	100	70	800,000
Tamarack, eastern	800	....	200	95	1,300,000

COMMON GRADE

Cedar, western red	570	600	125	64	1,000,000
northern and southern white	450	....	100	56	800,000
Port Orford	680	720	150	72	1,200,000
Alaska	680	....	150	72	1,200,000

Cypress, southern	680	....	225	80	1,200,000
Douglas fir,					
Coast Region	750	800	200	72	1,600,000
dense	875	930	235	84	1,600,000
Rocky Mtn. Region	530	560	200	68	1,200,000
Fir, balsam	450	....	100	56	1,000,000
golden, noble, silver, white	600	....	200	56	1,100,000
Hemlock, West Coast	680	720	200	60	1,400,000
eastern	600	....	200	56	1,100,000
Larch, western	680	720	200	80	1,300,000
Pine, southern	750	800	200	88	1,600,000
dense	875	930	235	103	1,600,000
California, Idaho and northern white, Pondosa and sugar	570	....	125	68	1,000,000
Norway	600	....	150	68	1,200,000
Redwood	600	640	125	56	1,200,000
Spruce, red, white, Sitka	600	640	125	68	1,200,000
Englemann	370	....	100	56	800,000
Tamarack, eastern	680	....	200	76	1,300,000

NOTE.—Values are those recommended by Forest Products Laboratory.

SAFE LOADS FOR WOODEN COLUMNS

1. The unit working stresses in compression parallel to grain for columns whose ratio of unsupported length to least dimension does not exceed 10 shall be not greater than that given for the species in the accompanying table of Working Stresses.

2. For columns the ratio of whose unsupported length to least dimension is greater than 10, the following formula shall be used until the reduction in allowable stress equals one-third the stress for short columns:

$$\frac{P}{A} = S\left[1 - \frac{1}{3}\left(\frac{l}{Kd}\right)^4\right]$$

where P = total load in pounds.
A = area in square inches.
$\frac{P}{A}$ = unit compressive stress.
S = safe stress in compression parallel to grain for short columns.
l = unsupported length in inches.
d = least dimension in inches.
E = modulus of elasticity.
K = the $\frac{l}{d}$ at the point of tangency of the parabolic and Euler curves, at which $\frac{P}{A} = \frac{2}{3}S$.

The value of K for any species and grade is

$$\frac{\pi}{2}\sqrt{\frac{E}{6S}}$$

3. For columns of greater length the Euler formula below, which includes factor of safety of 3 shall be used:

$$\frac{P}{A}=\frac{\pi^2}{36}\,\frac{E}{\left(\frac{l}{d}\right)^2}$$

4. Columns shall be limited in slenderness to $\frac{l}{d}=50$.

VALUES OF "K" FOR COLUMNS OF INTERMEDIATE LENGTH

Species	*Continuously Dry*		*Occasionally Wet*		*Usually Wet*	
	Select	*Common*	*Select*	*Common*	*Select*	*Common*
Cedar, western red	24.2	27.1	24.2	27.1	25.1	28.1
" Port Orford	23.4	26.2	24.6	27.4	25.6	28.7
Douglas Fir,						
Coast region	23.7	27.3	24.9	28.6	27.0	31.1
Dense	22.6	25.3	23.8	26.5	25.8	28.8
Rocky Mountain region	24.8	27.8	24.8	27.8	26.5	29.7
Hemlock, West Coast	25.3	28.3	25.3	28.3	26.8	30.0
Larch, western	22.0	24.6	23.1	25.8	25.8	28.8
Oak, red and white	24.8	27.8	26.1	29.3	27.7	31.1
Pine, southern		27.3	....	28.6	....	31.1
Dense	22.6	25.3	23.8	26.5	25.8	28.8
Redwood	22.2	24.8	23.4	26.1	25.6	28.6
Spruce, red, white, Sitka	24.8	27.8	25.6	28.7	27.5	30.8

STRENGTH OF COLUMNS OF INTERMEDIATE LENGTH

IN PER CENT OF STRENGTH OF SHORT COLUMNS

Values for the expression $\left[1-\frac{1}{3}\left(\frac{l}{Kd}\right)^4\right]$

in the formula: $\frac{P}{A}=S\left[1-\frac{1}{3}\left(\frac{l}{Kd}\right)^4\right]$

$$\text{PERCENTAGE}=\left[1-\frac{1}{3}\left(\frac{l}{Kd}\right)^4\right]$$

K																				
22	97	96	95	93	91	88	85	81	77	72	67									
23	98	97	95	94	92	90	87	84	81	77	72	67								
24	98	97	96	95	93	92	89	87	84	80	76	72	67							
25	98	98	97	96	94	93	91	89	86	83	80	76	72	67						
26	99	98	97	96	95	93	92	91	89	86	83	80	76	72	67					
27	99	98	98	97	96	95	93	92	90	88	85	82	79	74	71	67				
28	99	98	98	97	96	95	94	93	91	89	87	85	82	79	75	71	67			
29	99	99	98	98	97	96	95	94	92	91	89	87	84	82	79	75	71	67		
30	99	99	98	98	97	97	96	95	94	92	90	88	86	84	81	78	75	71	67	
31	99	99	99	98	98	97	96	95	94	93	92	90	88	86	84	81	78	75	71	67
$\frac{l}{d}$	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Ratio of Length to Least Dimension in Rectangular Timbers.

This table can also be used for columns not rectangular, the l/d being equivalent to .289 l/r, where r is the least radius of gyration of the section.

WORKING STRESSES

Pounds per Square Inch

For Material Complying with Basic Provisions for Structural Grades of American Lumber Standards

POSTS AND TIMBERS 6"x6" AND LARGER

Continuously Dry

Select Grade

Species	*Compression parallel to Grain Ratio of Length to Least Dimension (L/D)* 10	12	14	16	18	20	25	30	35	40	50	*Modulus of Elasticity*
Cedar, western red	700	686	674	656	629	592	438	304	224	171	110	1,000,000
Douglas fir, Coast Region	1175	1149	1127	1093	1045	975	702	487	358	274	175	1,600,000
Dense	1285	1251	1222	1176	1112	1022	702	487	358	274	175	1,600,000
Rocky Mountain Region	800	786	774	753	726	688	526	365	268	206	132	1,200,000
Hemlock, West Coast	900	885	872	852	823	783	614	426	313	240	153	1,400,000
Larch, western	1100	1068	1041	999	937	851	570	396	291	223	142	1,300,000
Pine, southern, dense	1285	1251	1222	1176	1112	1022	702	487	358	274	175	1,600,000
Redwood	1000	972	947	910	856	781	526	365	268	206	132	1,200,000
Spruce, red, white, Sitka	800	786	774	753	726	688	526	365	268	206	132	1,200,000

Common Grade

Species	10	12	14	16	18	20	25	30	35	40	50	*Modulus of Elasticity*
Cedar, western red	560	553	547	538	524	505	425	304	224	171	110	1,000,000
Douglas fir, Coast region	880	870	861	847	826	796	675	487	358	274	175	1,600,000
Dense	1025	1017	996	965	935	893	698	487	358	274	175	1,600,000
Rocky Mountain Region	640	632	627	617	602	582	500	365	268	206	132	1,200,000
Hemlock, West Coast	720	712	706	696	680	660	573	426	313	240	153	1,400,000
Larch, western	880	863	849	828	798	752	570	396	291	223	142	1,300,000
Pine, southern	880	870	861	847	826	796	675	487	358	274	175	1,600,000
Dense	1025	1017	996	965	935	893	698	487	358	274	175	1,600,000
Redwood	800	786	773	754	726	688	526	365	268	206	132	1,200,000
Spruce, red, white, Sitka	640	632	627	617	602	582	500	365	268	206	132	1,200,000

Note.—Values are those recommended by Forest Products Laboratory.

WORKING STRESSES

Pounds per Square Inch

FOR MATERIAL COMPLYING WITH BASIC PROVISIONS FOR STRUCTURAL GRADES OF AMERICAN LUMBER STANDARDS

POSTS AND TIMBERS 6"x6" AND LARGER

OCCASIONALLY WET BUT QUICKLY DRIED

SELECT GRADE

Species	*Compression parallel to Grain Ratio of Length to Least Dimension (L/D)*											*Modulus of Elasticity*
	10	12	14	16	18	20	25	30	35	40	50	
Cedar, western red	700	686	673	654	628	591	438	304	224	171	110	1,000,000
Douglas fir, Coast Region	1065	1045	1028	1003	968	915	702	487	358	274	175	1,600,000
Dense	1165	1139	1118	1083	1036	971	702	487	358	274	175	1,600,000
Rocky Mountain Region	800	785	772	753	728	688	526	365	268	206	132	1,200,000
Hemlock, West Coast	900	885	871	851	824	783	612	426	313	240	153	1,400,000
Larch, western	1000	976	955	922	877	810	570	396	291	223	142	1,300,000
Pine, southern, dense	1165	1139	1118	1083	1036	971	702	487	358	274	175	1,600,000
Redwood	900	879	861	834	794	738	526	365	268	206	132	1,200,000
Spruce, red, white, Sitka	750	738	728	712	690	657	525	365	268	206	132	1,200,000
COMMON GRADE												
Cedar, western red	560	552	546	537	523	504	425	304	224	171	110	1,000,000
Douglas fir, Coast Region	800	792	784	773	758	736	644	487	358	274	175	1,600,000
Dense	935	924	905	886	858	830	681	487	358	274	175	1,600,000
Rocky Mountain Region	640	632	625	616	602	582	502	365	268	206	132	1,200,000
Hemlock, West Coast	720	712	705	695	681	659	572	426	313	240	153	1,400,000
Larch, western	800	787	777	760	736	704	564	396	291	223	142	1,300,000
Pine, southern	800	792	784	773	758	736	644	487	358	274	175	1,600,000
Dense	935	924	905	886	858	830	681	487	358	274	175	1,600,000
Redwood	720	709	700	685	666	637	518	365	268	206	132	1,200,000
Spruce, red, white, Sitka	600	594	588	580	568	552	485	365	268	206	132	1,200,000

WORKING STRESSES

Pounds per Square Inch

For Material Complying with Basic Provisions for Structural Grades of American Lumber Standards

POSTS AND TIMBERS 6″x6″ AND LARGER

More or Less Continuously Damp or Wet

Select Grade

Species	*Compression parallel to Grain Ratio of Length to Least Dimension (L/D)*											*Modulus of Elasticity*
	10	12	14	16	18	20	25	30	35	40	50	
Cedar, western red........	650	638	629	614	594	565	437	304	224	171	110	1,000,000
Douglas fir, Coast Region..	905	893	883	867	846	814	683	487	358	274	175	1,600,000
Dense	990	974	961	940	910	871	698	487	358	274	175	1,600,000
Rocky Mountain Region.	700	690	681	669	651	623	514	365	268	206	132	1,200,000
Hemlock, West Coast.....	800	789	780	766	745	717	600	426	313	240	153	1,400,000
Larch, western	800	787	776	760	736	704	565	396	291	223	142	1,300,000
Pine, southern, dense......	990	974	961	940	910	871	698	487	358	274	175	1,600,000
Redwood	750	737	727	712	690	657	525	365	268	206	132	1,200,000
Spruce, red, white, Sitka..	650	642	635	625	611	589	500	365	268	206	132	1,200,000

Common Grade

Species	10	12	14	16	18	20	25	30	35	40	50	*Modulus of Elasticity*
Cedar, western red........	520	514	509	502	491	475	413	304	224	171	110	1,000,000
Douglas fir, Coast Region.	680	675	670	664	655	641	588	482	358	274	175	1,600,000
Dense.	795	785	777	767	753	730	642	482	358	274	175	1,600,000
Rocky Mountain Region.	560	554	551	544	535	521	465	365	268	206	132	1,200,000
Hemlock, West Coast.....	640	634	629	622	612	598	537	426	313	240	153	1,400,000
Larch, western	640	633	627	618	606	588	519	396	291	223	142	1,300,000
Pine, southern	680	675	670	664	655	641	588	482	358	274	175	1,600,000
Dense	795	785	777	767	753	730	642	482	358	274	175	1,600,000
Redwood	600	594	588	580	568	552	483	365	268	206	132	1,200,000
Spruce, red, white, Sitka..	520	515	512	507	500	489	446	365	268	206	132	1,200,000

Note.—Values are those recommended by Forest Products Laboratory.

STRUCTURAL GRADES OF LUMBER AND TIMBER AND THE METHOD OF THEIR DERIVATION

This subject-matter is printed in Vol. 30, pages 1206 to 1224, for year 1929.

CLASSIFICATION OF THE USES OF TIMBER AND LUMBER UNDER AMERICAN RAILWAY ENGINEERING ASSOCIATION SPECIFICATIONS

The grades recommended are those which would ordinarily be used. For work of the highest character, a grade higher could be used, and for temporary work, a grade lower.

In yard material, standard grades of one producing region compare as closely with those of other regions as the variations in the species will permit.

Structural grades apply equally to all species, hence the structural grades of American Lumber Standards can be applied to any species if grades conforming to the structural grades of American Lumber Standards are not included in the standard grades of the region producing that species.

Details of heartwood, sapwood, wane and square edge specification are not included in these grades but are left to the discretion of the person consulting this reference and ordering material.

1. Bridge and Construction Timber

A. COMBINATION AND HOWE TRUSS SPANS

1. Compression members	Select Structural Posts and Timbers
2. Tension	Select Structural Joist and Plank
3. Diagonals subject to reversal of stress	Select Structural Posts and Timbers
4. Floor Beams	Select Structural or Dense Select Structural Beams and Stringers
5. Stringers	
6. Ties	Select Structural Timbers
7. Guard Timbers	Common Structural Timbers
8. Railing	No. 1 Common Dimension
9. Stiffeners	No. 1 Common Dimension
10. Splices	No. 1 Common Dimension
11. Nailing Strips	No. 1 Common Dimension
12. Grillage	Common Structural Timbers
13. Deck Plank	No. 1 Common Dimension
14. Bridging	No. 2 Common Boards

B. PILE AND FRAME TRESTLES

1. Sills and Mud Sills	Select Structural Timbers
2. Posts	Select Structural Posts
3. Caps	Select Structural Timbers
4. Sash Bracing	Common Structural Plank
5. Cross Bracing	Common Structural Plank
6. Longitudinal Bracing	Common Structural Plank
7. Girts	Common Structural Timbers
8. End Planks	Common Structural Plank
9. Stringers	Select Structural or Dense Select Structural Stringers
10. Ties	Select Structural Timbers
11. Guard Timbers	Common Structural Timbers

B.	PILE AND FRAME TRESTLES—Continued	
12.	Planking for Ballasted Deck	Select Structural Plank
13.	Railing	No. 1 Common Dimension
C.	FALSEWORK	
1.	Sills and Mud Sills	Common Structural Timbers
2.	Posts	Common Structural Posts
3.	Caps	Common Structural Timbers
4.	Stringers	Select Structural Stringers
5.	Truss Timbers	Common Structural Timbers
6.	Centering	No. 1 Common Dimension
7.	Lagging	No. 1 Common Dimension
8.	Bracing	Common Structural Plank
9.	Wedges	No. 1 Common Dimension
10.	Scaffolding	No. 2 Common Dimension
D.	CONCRETE FORMS	
1.	Dimension Lumber	No. 1 Common Dimension
2.	D & M Planks	No. 2 Common Boards
3.	Bracing	No. 2 Common Boards
E.	TANKS AND SUPPORTS	
1.	Sills	Common Structural Timbers
2.	Posts	Select Structural Posts
3.	Caps	Select Structural Timbers
4.	Bracing	Common Structural Plank
5.	Joists	Select Structural Joists
6.	D & M Flooring	C Flooring
7.	Staves	C Tank Stock
8.	Rafters	No. 1 Common Dimension
9.	Roof	No. 1 Common Shiplap
10.	Ladders, Etc.	C Ladder Stock
11.	Frost-box Material	No. 1 Common Shiplap
F.	DOCKS AND WHARVES	
1.	Timber Sheet Piling	Common Structural Timbers
2.	Timber in Cribs	Common Structural Timbers
3.	Caps	Select Structural Timbers
4.	Stringers	{ Select Structural or { Dense Select Structural Stringers
5.	Bracing	Common Structural Plank
6.	Guard Timbers	Common Structural Timbers
7.	Ties	Select Structural Timbers
8.	Plank Decking	Select Structural Plank
9.	Mooring Posts	Select Structural Timbers
10.	Fenders and Wales	Common Structural Timbers
11.	Warehouse, see Frame Buildings	
G.	COALING STATIONS AND ORE STATIONS	
1.	Sills and Mud Sills	Common Structural Timbers
2.	Posts	Select Structural Posts
3.	Caps	Select Structural Timber
4.	Bracing	Common Structural Plank
5.	Stringers	{ Select Structural or { Dense Select Structural Stringers
6.	Joists	Select Structural Joists
7.	Bin Lining	No. 1 Common Dimension
8.	Rafters	No. 1 Common Dimension
9.	Flooring	No. 1 Common Boards
10.	Chutes	No. 1 Common Boards
11.	Decking	No. 1 Common Boards
12.	Coal Pockets and Bins	No. 1 Common Dimension
13.	Roofing	No. 2 Common Shiplap

H. TUNNELS

1.	Posts	Select Structural Timbers
2.	Sills	Select Structural Timbers
3.	Caps	Select Structural Timbers
4.	Segments	Select Structural Timbers
5.	Lagging	No. 1 Common Dimension
6.	Struts	No. 1 Common Dimension

J. CAISSON	Select Structural Timbers

2. Frame Buildings.

A. STATION BUILDINGS, PASSENGER, FREIGHT, PLATFORM SHELTERS

1.	Caps	Common Structural Timbers
2.	Sills	Common Structural Timbers
3.	Posts	Common Structural Timbers
4.	Stringers	Select Structural Stringers
5.	Joists	Common Structural Joists
6.	Bridging	No. 3 Common Boards
7.	Sub-Flooring	No. 2 Common Shiplap
8.	Finish Flooring	A or B Flooring (for Natural Finish) C or D Flooring (for Paint Finishes)
9.	Studding and Plates	No. 1 Common Dimension
10.	Sheathing	No. 2 Common Shiplap
11.	Furring	No. 2 Common Strips
12.	Siding	B or C Siding
13.	Ceiling	B Ceiling (for Natural Finishes) C Ceiling (for Paint Finishes)
14.	Truss Timbers	No. 1 Common Dimension
15.	Purlins	No. 1 Common Dimension
16.	Rafters	No. 1 Common Dimension
17.	Roof Boards	No. 2 Common Shiplap
18.	Shingles on Roofs and Side Walls	A (for roofs) B (for Side Walls)
19.	Door and Window Frames	C Finish
20.	Outside Finish Lumber	C Finish
21.	Inside Finish Lumber	A or B Finish (for Natural Finishes) C or D Finish (for Paint Finishes)
22.	Millwork a. Mouldings	A Moulding Stock or C Moulding Stock
	b. Stairs	A Finish or C Finish
23.	Partitions	B Partition or C Partition
24.	Shelving	C Finish

B. ENGINE HOUSE

1.	Caps	Common Structural Timbers
2.	Sills	Common Structural Timbers
3.	Posts	Common Structural Timbers
4.	Stringers	Select Structural Stringers
5.	Joists	Select Structural Joists
6.	Bridging	No. 3 Common Boards
7.	Flooring	No. 1 Common Dimension
8.	Pit Timbers	Common Structural Timbers
9.	Studding	No. 1 Common Dimension
10.	Furring	No. 2 Common Strips
11.	Siding	C or D Siding

B. Engine House.—Continued

12.	Ceiling	C Ceiling
13.	Truss Lumber	No. 1 Common Dimension
14.	Purlins	No. 1 Common Dimension
15.	Rafters	No. 1 Common Dimension
16.	Roof Boards	No. 2 Common Shiplap
17.	Shingles	A
18.	Door and Window Frames	C Finish
19.	Outside Finish Lumber	C or D Finish
20.	Inside Finish Lumber	C Finish
21.	Millwork	C Finish
22.	Sleepers	No. 2 Common Dimension

C. Machine Shops.

1.	Caps	Common Structural Timbers
2.	Sills	Common Structural Timbers
3.	Posts	Common Structural Timbers
4.	Stringers	Select Structural Stringers
5.	Joists	Select Structural Joists
6.	Bridging	No. 3 Common Boards
7.	Flooring	No. 1 Common Dimension
8.	Studding	No. 1 Common Dimension
9.	Sheathing	No. 2 Common Shiplap
10.	Furring	No. 2 Common Strips
11.	Siding	C or D Siding
12.	Ceiling	C or D Ceiling
13.	Truss Timbers	Select Structural Timbers
14.	Purlins	No. 1 Common Dimension
15.	Rafters	No. 1 Common Dimension
16.	Roofing Boards	No. 2 Common Shiplap
17.	Shingles	A
18.	Door and Window Frames	C Finish
19.	Outside Finish Lumber	C Finish
20.	Inside Finish Lumber	C Finish
21.	Millwork	C Finish
22.	Sleepers	No. 2 Common Dimension

D. Section Houses

1.	Posts	No. 2 Common Dimension
2.	Sills	No. 2 Common Dimension
3.	Caps	No. 2 Common Dimension
4.	Joists	No. 1 Common Dimension
5.	Bridging	No. 3 Common Boards
6.	Sub-flooring	No. 2 Common Shiplap
7.	Finish Flooring	B Flooring (for Natural Finishes) C Flooring (for Paint Finishes)
8.	Studding and Plates	No. 1 Common Dimension
9.	Sheathing	No. 2 Common Shiplap
10.	Furring	No. 2 Common Strips
11.	Siding	C or D Siding
12.	Ceiling	C or D Ceiling
13.	Rafters	No. 1 Common Dimension
14.	Roof Boards	No. 2 Common Shiplap
15.	Shingles	A
16.	Door and Window Frames	C Finish
17.	Outside Finish Lumber	C Finish
18.	Inside Finish Lumber	C Finish
19.	Millwork	C Finish

E. Miscellaneous Small Buildings

1.	Posts	No. 2 Common Dimension
2.	Sills	No. 2 Common Dimension
3.	Caps	No. 2 Common Dimension
4.	Joists	Common Structural Joists
5.	Bridging	No. 3 Common Boards
6.	Sub-Flooring	No. 2 Common Shiplap
7.	Finish Flooring	C Flooring
8.	Studding and Plates	No. 1 Common Dimension
9.	Sheathing	No. 2 Common Shiplap
10.	Furring	No. 3 Common Strips
11.	Siding	C or D Siding
12.	Ceiling	C or D Ceiling
13.	Rafters	No. 1 Common Dimension
14.	Roof Boards	No. 2 Common Shiplap
15.	Shingles	C
16.	Door and Window Frames	C Finish
17.	Outside Finish Lumber	C Finish
18.	Inside Finish Lumber	C Finish
19.	Millwork	C Finish

F. Warehouses

1.	Caps	Common Structural Timbers
2.	Sills	Common Structural Timbers
3.	Posts	Common Structural Timbers
4.	Stringers	Select Structural Stringers
5.	Joists	Select Structural Joists
6.	Bridging	No. 2 Common Boards
7.	Sub-Flooring	No. 2 Common Shiplap
8.	Finish Flooring	C Flooring
9.	Studding and Plates	No. 1 Common Dimension
10.	Sheathing.	No. 2 Common Shiplap
11.	Furring	No. 2 Common Strips
12.	Siding	C or D Siding
13.	Ceiling	C or D Ceiling
14.	Truss Timbers	No. 1 Common Dimension
15.	Purlins	No. 1 Common Dimension
16.	Rafters	No. 1 Common Dimension
17.	Roof Boards	No. 2 Common Shiplap
18.	Shingles	A
19.	Door and Window Frames	C Finish
20.	Outside Finish Lumber	C Finish
21.	Inside Finish Lumber	C Finish
22.	Millwork	C Finish
23.	Sleepers	No. 2 Common Strips

G. Ice Houses.

1.	Sills	Common Structural Timbers
2.	Caps	Common Structural Timbers
3.	Posts	Common Structural Timbers
4.	Stringers	Select Structural Stringers
5.	Joists	No. 1 Common Dimension
6.	Bridging	No. 2 Common Boards
7.	Sleepers	No. 2 Common Strips
8.	Sub-Flooring	No. 2 Common Shiplap
9.	Finish Flooring	C Flooring
10.	Studding	No. 1 Common Dimension
11.	Sheathing	No. 2 Common Shiplap
12.	Furring	No. 3 Common Strips
13.	Siding	C or D Siding
14.	Ceiling	C or D Ceiling

3. Miscellaneous Roadway Material

A. Crossing Plank.	No. 1 Common Dimension
B. Platforms.	
1. Posts	No. 1 Common Dimension
2. Caps	No. 1 Common Dimension
3. Sills	No. 1 Common Dimension
4. Stringers	Select Structural Stringers
5. Joists	Select Structural Joists
6. Bridging	No. 3 Common Boards
7. Planking	No. 1 Common Dimension
8. Railing	No. 1 Common Dimension
9. Steps	No. 1 Common Boards
10. Skids	No. 1 Common Dimension
C. Stock Guards.	
1. Posts	No. 1 Common Dimension
2. Ties	Select Structural Timbers
3. Wing Fences and Aprons	No. 1 Common Boards
4. Slats	No. 1 Common Boards
5. Fillers	No. 2 Common Boards
D. Signs and Posts.	
1. Posts	No. 1 Common Dimension
2. Bracing	No. 2 Common Dimension
3. Sign Boards	C Finish
4. Moulding	C Moulding Stock
E. Fencing, Including Snow Fence.	
1. Posts	No. 1 Common Dimension
2. Bracing	No. 2 Common Boards
3. Stringers	No. 1 Common Dimension
4. Fence Boards	No. 2 Common Boards
5. Gate Materials	No. 1 Common Boards
6. Stakes	No. 2 Common Boards
F. Culverts and Drains.	
1. Sills	Common Structural
2. Bracing	No. 2 Common Board
3. Timbers	Common Structural Timbers
4. Planking	No. 2 Common Dimension
5. Grillage	Common Structural Timbers
G. Stock Pens.	
1. Posts	No. 1 Common Dimension
2. Sills	No. 1 Common Dimension
3. Fencing	No. 1 Common Dimension
4. Studding	No. 1 Common Dimension
5. Sheathing	No. 2 Common Shiplap
6. Rafters	No. 1 Common Dimension
7. Roof Boards	No. 2 Common Shiplap
8. Shingles	B
9. Outside Finish Lumber	C Finish
H. Poles.	Select Structural Timbers
I. Conduits.	No. 1 Common Dimension
J. Bumping Blocks.	Select Structural Timbers

[17]SPECIFICATIONS FOR CONSTRUCTION OAK

General Instructions

Those who are not familiar with the anatomy of the oak tree should, when reading over these rules, take into consideration that the rule describes the poorest piece that goes into the grade and that a large per cent is above the grade described.

Definition of Oak for Construction Purposes

1. The term "Construction Oak" means all such products of oak in which the strength and durability of the timber is the controlling element in its selection and use. The following is a list of products which are recommended for consideration as "Construction Oak."

2. Firsts are to be sound and free from heart shakes and checks, but may have other defects as follows:

Construction Oak

Trestle and Bridge Timbers.—Mud Sills, Stringers, Caps, Posts, Bracing, Bridge Ties, Struts, Guard Rails, Girts, Sash and Sway Braces.

Docking and Platform Timbers.—Mud Sills, Posts, Bracing Caps, Stringers, Joists, Dock and Platform or Flooring Plank and Wales.

Platform or Flooring Plank can be either square-edged or matched.

Framing for Building.—Mud sills, Posts, Girders, Framing Joists, etc.

Bridge and Crossing Plank.—Railroad Crossing Plank, Bridge Floor Planking.

Sheet Piles.—Same as Crossing Plank, except may contain an unlimited amount of heart.

Round Piling.

Stock-Guards.

Track or Bumper Posts.

Standard Names for Construction Oak

Unless specifically mentioned, the terms "White Oak" and "Red Oak" include the following:

White Oak	*Red Oak*
White Oak	Red Oak
Chestnut or Tanbark Oak	Pin Oak
Burr or Mossy Cup Oak	Black Oak
Rock Oak	Water Oak
Post or Iron Oak	Willow Oak
Overcup Oak	Spanish Oak
Live Oak	Turkey Oak
Basket or Cow Oak	Black Jack or Barn Oak
Swamp Post Oak	Shingle or Laurel Oak
Yellow or Chinquapin Oak	Scarlet Oak

The term "Mixed Oak" means any kind of oak.

[17] Adopted, Vol. 22, 1921, pp. 525, 1072.

SPECIFICATIONS FOR STRUCTURAL OAK TIMBERS

General Requirements

1. Except as noted, all Structural Timbers shall be White Oak, to be sound timber and sawed specified sizes, free from ring shakes, crooked grain, rotten knots, large knots in groups, rot, dote, wane in amounts greater than allowed in these specifications.

Boxed Hearts

2. Boxed Hearts are permitted in pieces of 5 by 5 inches square and larger. The center of the heart should be boxed as near the center of the piece as practical, and not to exceed 30 per cent of the pieces can have the center of the heart nearer than 1½ inches from any face; 20 per cent may show one heart face, corner or edge, not to exceed 75 per cent of the length of the piece.

Wane

1. The term 20 per cent of number of pieces or amount shipped refers to each item and size of each car shipped.

2. Pieces 5x5 to 8x8 inches square may show 1 inch wane, side measurement, on any two corners or edges, and this wane not to exceed more than 25 per cent of the length of the piece singly, or 50 per cent in aggregate. In the absence of wane on all corners excepting one, the one corner may contain wane 50 per cent of the length of the piece as above described; not to exceed 20 per cent of number of pieces may have this defect.

3. Pieces over 8x8, including 12x12 inches square, may show 1½ inch wane, side measurement, edge of any two corners or edges, and this wane not to exceed more than 33⅓ per cent of the length of the piece singly or 66⅔ per cent in aggregate. In the absence of wane on all of the length of the piece as above described, not to exceed 20 per cent of the number of pieces may have this defect.

4. Pieces over 12 by 12 inches square may show 1¾ inch side measurement, any two corners or edges, and this wane not to exceed more than 40 per cent of the length of the piece singly, or 80 per cent in aggregate, in the absence of wane on all corners, excepting one, the corner may contain wane 80 per cent of the length of the piece as above described; not to exceed 20 per cent of number of pieces may have this defect.

5. In event that pieces have two faces as wide as above described and two faces narrower, the proportion of the amount of wane is admissible.

6. Pieces 1 inch to 5 inches thick, not exceeding 8 inches wide, are governed by defect specifications above mentioned, with the exception that they shall not contain wane, and not to exceed 20 per ent of pieces 2 inches and thicker may show sound heart on one face; pieces under 2 inches thick must be free of heart. Pieces 8 inches and wider may contain wane as per paragraphs (b) and (d).

7. Rough sizes of Structural Timber shall not vary more than ¼ inch from specified size. Dressed sizes shall be ½ inch less than nominal size after dressing.

Bridge, Dock, Crossing Plank

1. Lengths, cut to order.
Widths, cut to order.
Thickness, cut to order.

2. Sizes cut to order, probably 2 inches, 3 inches and 4 inches thick, 6 inches, 8 inches, 10 inches and 12 inches wide, 12 feet, 14 feet and 16 feet long.

3. This product is intended to work full one good sound face, and this face side must be square edge. Sound knots, small pin and spot worm holes no defect on face side.

4. Must be free from rot and shake; practically square edges, admitting 1 inch of wane on each edge of reverse face, running two-thirds the length. Sound hearts on one side, rafting pin holes, knot holes or grub holes not exceeding 2 inches in diameter admitted.

Sheet Piles

Same as Ties, except that it may contain sound heart in heart check.

Stock-Guards

To be governed by specifications for Construction Oak.

Track End or Bumping Posts

To be governed by specifications for Structural Timbers.

[18]MERITS OF GALVANIZED IRON FASTENINGS FOR TIMBER TRESTLES

(1) Creosoted timber has a tendency to protect from corrosion any plain iron or steel fastenings which are embedded in the timber.

(2) The durability of such fastenings is at least equal to that of the creosoted timber used in trestles.

(3) In the use of timber treated with straight creosote, drift bolts or other fastenings being entirely covered by the timber, it is good practice to use plain iron or steel.

(4) Such fastenings as are exposed to the action of brine drippings may be galvanized, but the information as to the increased life of fastenings so treated is not sufficient to state definitely that the expense of galvanizing is justified.

(5) It is not necessary to use galvanized fastenings in creosoted timber structures over salt water.

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[18] Adopted, Vol. 18, 1917, pp. 583, 1471.

COMMITTEE VIII

MASONRY

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[1]DEFINITIONS

GENERAL

Abutment.—A supporting wall carrying the end of a bridge or span and generally sustaining the pressure of the abutting earth.

Arch Masonry.—That portion of the masonry in the arch ring only, or between the intrados and the extrados.

Arris.—The external edge formed by two surfaces, whether plain or curved, meeting each other.

Batter.—The slope or inclination of the face or back of a wall from a vertical plane.

Bench Wall.—The abutment or side wall of a culvert.

Block Rubble.—Field or rough stone of large or massive size, as it comes from the quarry.

Cement.—A material of one of the two classes, Portland and natural, possessing the property of hardening into a solid mass when mixed with water.

Cement, Natural.—Natural cement is the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

Cement, Portland.—Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

Centering.—A temporary support used in arch construction. (Also called centers.)

Coping.—A top course of stone or concrete, generally slightly projecting, to shelter the masonry from the weather, or to distribute the pressure from exterior loading.

Culvert.—A small opening through a roadway or embankment. (Note.—The differentation between culvert and bridge is usually determined by arbitrary limits of span, depth of cover, etc.)

Dowels.—Metal bars used to connect two sections of masonry. (See definition of "Dowel" under "Stone and Brick Masonry.")

Extrados.—The outer or convex surface of an arch.

Final Set.—A stage of the process of setting marked by certain hardness. (See Cement Specifications.)

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[1] Adopted, Vol. 7, 1906, pp. 596-601, 619; Vol. 12, Part 1, 1911, pp. 478, 579; Vol. 16, 1915, pp. 794, 1175; Vol. 19, 1918, pp. 721, 1227; Vol. 21, 1920, pp. 84, 1354; Vol. 25, 1924, pp. 659, 1337; Vol. 30, 1929, pp. 804, 1464.

Flush (adj.)—Having the surface even or level with an adjacent surface.

Flush (verb).—(1) To fill. (2) To bring to a level. (3) To force water to the surface of mortar or concrete by compacting or ramming.

Footing.—A foundation course.

Foundation.—(1) That portion of a structure usually below the surface of the ground, which distributes the pressure upon its support. (2) Also applied to the natural support itself; rock, clay, etc.

Foundation Bed.—The surface on which a structure rests.

Grout (noun).— A fluid mixture of cement and water or of cement, sand and water.

Grout (verb).—To fill the joints and smaller voids in masonry with grout.

Initial Set.—An early stage of the process of settling, marked by certain hardness. (See Cement Specifications.)

Intrados.—The inner or concave surface of an arch.

Lagging.—Strips used to carry and distribute the weight of an arch to the ribs or centering during its construction.

Lock.—Any special device or method of construction used to secure a bond in the work.

Masonry.—Masonry, in its widest sense, includes all construction of stone or kindred substitute materials, in which the separate pieces are either placed together, with or without cementing material to join them; or encased in a matrix of firmly cementing material.

In usual practice, the word "Masonry" is qualified by some proper term to more particularly describe the masonry under consideration, such as stone, concrete, brick, etc.

Mortar.—A mixture of fine aggregate, cement and/or lime and water used to bind together the materials of concrete, stone or brick in masonry or to cover the surface of the same.

Parapet.—A wall or barrier on the edge of an elevated structure for protection or ornament.

Pier.—An intermediate support for arches or other spans.

Pointing.—Filling joints or defects in the face of a masonry structure.

Retaining Wall.—A wall for sustaining the pressure of earth or filling deposited behind it.

Sand.—(See definition under "Concrete Masonry.")

Set (noun).—The change from a plastic to a solid or hard state.

Slope Wall.—A wall to protect the slope of an embankment or cut.

Soffit.—The under side of a beam, slab, arch, lintel or other projection.

Spandrel Wall.—The wall above the extrados of an arch and below the coping or the string course.

Standard Sand.—(See definition under "Concrete Masonry.")

Wing Wall.—An extension of an abutment wall to retain the adjacent earth.

STONE AND BRICK MASONRY

Ashlar.—Face stone, usually of rectangular dimensions, squared or cut on beds, face and ends and sometimes on back.

Backing.—That portion of a masonry wall or structure built in the rear of the face course.

Bed.—The top or bottom of a stone. (See Course Bed; Natural Bed; Foundation Bed.)

Bed Joint.—A horizontal joint, or one perpendicular to the line of pressure.

Bond.—In stone or brick masonry, the mechanical disposition of stone, brick or other building blocks by overlapping to break joints. (See English Bond; Flemish Bond.)

Broken Coursed.—Laid with parallel, but not continuous, bed joints. (See Coursed; Uncoursed.)

Build.—A vertical joint.

Clamp.—An instrument for lifting stone so designed that its grip on the surface of the stone is increased as the load is applied. That portion engaging the stone is of wood attached to a steel shoe, which in turn is hinged to the shank of the clamp in such a manner as to adjust itself to the surface of the body lifted.

Course.—Each separate layer in stone or brick masonry.

Course Bed.—Stone, brick or other building material in position, upon which other material is to be laid.

Coursed.—Laid with continuous bed joints. (See Broken Coursed; Uncoursed.)

Cramp.—A bar of iron having its ends turned at right angles to the body, to end holes in the upper side or face of adjacent stones.

Dimension Stone.—A block of stone cut to specified dimensions.

Dowel.—A two-piece steel instrument used in lifting stone. The dowel engages the stone by means of two holes drilled into the stone at an angle of about 45 degrees pointing toward each other. The dowel is not keyed in place. (See definition of Dowel under General Definitions.)

Draft.—A line on the surface of a stone cut to the breadth of the chisel.

Dressing.—The finish given to the surface of stones. (See Smooth; Fine-Pointed; Rough-Pointed; Scabbled; Rock-Faced.)

Dry Masonry.—Masonry in which stones are built up without the use of mortar. (See Masonry under General Definitions.)

English Bond.—That disposition of bricks in a structure in which each alternate course is composed entirely of headers or of stretchers. (See Bond.)

Fine Pointed.—Having irregular surface, the variations of which do not exceed one-quarter inch from the pitch line. (See Dressing.)

Flemish Bond.—That disposition of bricks in a structure in which the headers and stretchers alternate in each course, the header being so placed that the outer end lies on the middle of a stretcher in the course below. (See Bond.)

Header.—A stone which has its greatest length at right angles to the face of the wall, and which bonds the face stones to the backing.

Joint.—The narrow space between adjacent stones, bricks or other building blocks, usually filled with mortar.

Lewis.—A four-piece steel instrument used in lifting stone. (The lewis engages the stone by means of a triangular-shaped hole into which it is keyed.)

Natural Bed.—The surfaces of a stone parallel to its stratification.

Paving.—Regularly placed stone or brick forming a floor.

Pitch (verb).—To square a stone.

Pitched.—Having the arris clearly defined by a line beyond which the rock is cut away by the pitching chisel so as to make approximately true edges.

Ring Stones.—The end voussoirs of an arch.

Riprap.—Rough stone of various sizes placed compactly or irregularly to prevent scour by water.

Rock-Faced.—Presenting irregular projecting face, without indications of tool mark. (See Dressing.)

Rough Pointed.—Having irregular surface, the variations of which do not exceed one-half inch from the pitch line. (See Dressing.)

Rubbed.—A fine finish made by rubbing with grit or sandstone.

Rubble.—Field stone or rough stone as it comes from the quarry. When it is of a large or massive size it is termed block rubble.

Scabbled.—Having irregular surface, the variations of which do not exceed three-quarters inch from the pitch line. (See Dressing.)

Smooth.—Having surface, the variations of which do not exceed one-sixteenth inch from the pitch line. (See Dressing.)

Spall (noun).—A chip or small piece of stone broken from a large block.

Stretcher.—A stone which has its greatest length parallel to the face of the wall.

Uncoursed.—Laid without regard to courses. (See Coursed; Broken Coursed.)

Voussoirs.—The individual stones forming an arch. They are always of truncated wedge form.

CONCRETE MASONRY

Acid Treated Finish.—Having surface formed by dissolving cement with acid together with scrubbing to expose the aggregate. (See Finish.)

Aggregate.—The inert material used in making concrete. (See Pre-mixed Aggregate; Fine Aggregate; Coarse Aggregate.)

Cast-in-place Piles.—Piles which are cast in holes in the ground. (See Pre-Molded Concrete Piles.)

Coarse Aggregate.—The coarser inert material used in making concrete, usually considered to include that material which is retained on a sieve having four meshes per linear inch. The upper limit of its size depends on various conditions, but it seldom exceeds three inches. (See Aggregate.)

Concrete.—A compact mass of broken stone, gravel or other suitable material assembled together with cement mortar and allowed to harden. (See Reinforced Concrete; Rubble Concrete.)

Construction Joint.—A joint or break between successive deposits of concrete, usually to facilitate construction. (See Expansion Joint.)

Course.—Each separate layer in concrete. (See definition under Stone and Brick Masonry.)

Crushed Slag.—Air-cooled, blast-furnace slag of sizes specified under "Coarse Aggregate."

Crushed Stone.—Crushed natural rock of sizes specified under "Coarse Aggregate."

Crusher-Run Rock.—The unscreened output of the stone crusher.

Expansion Joint.—A joint or break in the mass concrete to provide for expansion. (See Construction Joint.)

Faced Surfaces.—Having surface formed by placing a special aggregate not less than one inch next to the forms and contiguous with the body concrete. (See Finish.)

Fine Aggregate.—The finer inert material used in making concrete, usually considered to include that material passing a sieve having four meshes per linear inch. (See Aggregate.)

Finish.—The finish given to surfaces of concrete. (See Acid-Treated Finish; Faced Surfaces; Rubbed Finish; Sand Blast Finish; Spaded Finish; Tooled Finish; Unfaced Surface; Washed or Scrubbed Finish.)

Form.—A temporary structure or mold in which to cast concrete.

Gravel, Bank-Run Gravel.—Normal product of a gravel bank, including pebbles and sand in varying proportions.

Joint.—(See Construction Joint; Expansion Joint.)

Laitance.—A film or layer of scum consisting of the extremely fine particles which separate from freshly deposited mortar or concrete and collect on the top surface.

Monolithic Concrete Construction.—The building of concrete built without joints by a continuous operation.

Pre-Mixed Aggregate.—A mixture of fine and coarse aggregate. (See Aggregate.)

Pre-Molded Concrete Piles.—Piles which are molded previous to driving. (See Cast-in-place Piles.)

Reinforced Concrete.—Concrete in which steel or other metal is embedded in such a manner that both concrete and metal act in unison to resist stresses. (See Concrete.)

Rubbed Finish.—Having surface treated by rubbing with Carborundum or cement bricks, or wooden floats to remove all form marks and irregularities. (See Finish.)

Rubble Concrete.—Concrete in which rubble stone are embedded. (See Concrete.)

Sand.—The finely divided material, generally of a siliceous nature, resulting from the reduction of rock by natural forces to the sizes included under fine aggregate. (See Standard Sand.)

Sand Blast Finish.—Having surface formed by the wearing effect of the sand blast. (See Finish.)

Spaded Finish.—Having surface formed by spading coarse aggregate back from the form into the mass concrete, so as to bring a surface of mortar next to the form. (See Finish.)

Standard Sand.—A natural sand from Ottawa, Illinois, screened to pass a No. 20 sieve, and retained on a No. 30 sieve.

Stone Screenings.—Crushed natural rock of sizes defined under "Fine Aggregate." (See Aggregate.)

Tooled Finish.—Having surface formed by dressing with bush hammer, crandall or other desired tool to a uniform depth and finish. (See Finish.)

Tremie.—A cylindrical or other form of tube, with a funnel top or pocket used for depositing concrete in water.

Unfaced Surface.—Having surface formed by careful grading of the entire mass mixture and spading mixture to prevent voids leaving the coarse aggregate next to the forms. (See Finish.)

Washed or Scrubbed Finish.—Having surface formed by rubbing or scrubbing to expose the aggregate.

SPECIAL CEMENTS AND ADMIXTURES

Quick Setting Portland Cement.—A Portland cement which stiffens and sets more quickly than ordinary Portland cement under similar conditions.

High Early Strength Cement.—A cement which will produce concrete having as high strength in a few days as ordinary Portland cement in twenty-eight days, used in the usual manner and proportions.

Supercement.—A trade name for a cement to which a small percentage of "Catacoll" (tannin) has been added with the gypsum at the time of grinding.

Admixture.—Any material, other than cement, water, or aggregate, added to the concrete mixture to effect certain changes in the properties of the concrete.

Integral Waterproofing.—Any admixture other than cement, water or aggregate added to the concrete mixture for the purpose of increasing the water tightness of the concrete.

Accelerators.—Any admixture other than cement, water, or aggregate added to the concrete mixture for the purpose of securing a more rapid hardening of the concrete.

[2]SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE, PLAIN AND REINFORCED

(I) MATERIALS

CEMENT

Portland Cement

1. The cement shall meet the requirements of the American Railway Engineering Association's "Specifications for Portland Cement." Cement that has hardened or partially set shall not be used.

FINE AGGREGATE

General

2. Fine aggregate shall consist of sand or other approved inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances.

Grading

3. Fine aggregate shall range in size from fine to coarse within the limits indicated below, percentage by weight:

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[2] Adopted, Vol. 28, 1927, pp. 1056, 1451; Vol. 29, 1928, pp. 607, 1399; Vol. 30, 1929, pp. 783, 1461.

Passing through No. 4 sieve......		100 per cent
Passing through No. 50 sieve.....	Not more than	30 per cent
	Not less than	10 per cent
Passing through No. 100 sieve, when screened dry...........	Not more than	6 per cent
Volume removed by sedimentation .	Not more than	3 per cent

Organic Impurities in Sand

4. Natural sand which shows a color darker than the standard color when tested in accordance with the Colorimetric Test for Sands (Standard Method of Tests for Organic Impurities in Sands for Concrete, serial designation C. 40-27 American Society for Testing Materials) shall not be used unless the concrete made with the materials and in the proportions to be used on the work is shown by tests to be of the required strength.

COARSE AGGREGATE

General

5. Coarse aggregate shall consist of crushed stone, gravel, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic or other deleterious matter.

Slag

6. Provided the contract specifically permits the use of crushed slag as a coarse aggregate, it shall be air cooled, blast furnace slag, conforming to all the requirements for coarse aggregate specified in paragraph five. The crushed slag shall weigh not less than seventy (70) lb. per cubic foot, and shall be obtained only from such banks as have the approval of the Engineer. All slag used shall have seasoned in the bank for a period not less than one (1) year, unless in the opinion of the Engineer a shorter period is sufficient.

Grading

7. Coarse aggregate shall grade in size from fine to coarse, preferably within the following percentages, by weight:

Passing maximum size sieve......	Not less than	95 per cent
Passing sieve ½ the maximum....	Not more than	75 per cent
	Not less than	40 per cent
Passing No. 4 sieve..............	Not more than	6 per cent

The maximum size of coarse aggregate shall be not more than three inches and shall be not more than four-fifths of the minimum clear space between reinforcement bars or mesh.

Mixing Water

8. Mixing water shall be free from oil, acid, and injurious amounts of vegetable matter, alkalies or other salts.

STORAGE OF CEMENT AND AGGREGATES

Storing Cement

9. The cement shall be stored in a weather tight structure with the floor raised not less than one foot from the ground, in such manner

as to permit easy access for proper inspection and identification of each shipment. Cement that has hardened or partially set shall be removed from the site and not used in the work.

Storing Aggregates

The fine and coarse aggregates shall be stored separately and in such manner as to avoid the inclusion of dirt and other foreign material in the concrete. Coarse aggregate shall be unloaded and piled in such manner as to maintain the grading of the sizes.

(II) STEEL REINFORCEMENT

Quality

10. Steel rods or bars used for reinforcing shall conform to the requirements of the American Railway Engineering Association's "Specifications for Billet-Steel Concrete Reinforcement Bars."

Structural steel shapes used for reinforcing shall conform to the requirements of the American Railway Engineering Association's "Specifications for Steel Railway Bridges."

Size of Bars

11. Reinforcement bars shall conform to the areas and equivalent sizes shown in the following table:

Sizes and Areas of Reinforcement Bars

	Area Sq. In.	
Size of Bar In.	*Round Bar*	*Square Bar*
3/8	0.110	....
1/2	0.196	0.250
5/8	0.306	....
3/4	0.441	....
7/8	0.601	....
1	0.785	1.000
1-1/8	....	1.265
1-1/4	....	1.562

Deformed Bars

12. An approved deformed bar shall be one that will develop a bond at least 25 per cent greater than that of a plain round bar of equivalent cross-sectional area. The areas of deformed bars shall be determined by the minimum cross-section thereof.

Wire

13. Wire for concrete reinforcement shall be cold drawn steel wire.

Spirals

14. Spirals for column reinforcement shall be cold drawn steel wire and consist of evenly spaced continuous spirals held firmly in place and true to line by at least three vertical spacer bars. At the ends of all spirals and at points of splice, the outside diameter shall be maintained.

(III) WORKMANSHIP

Proportioning and Mixing

General

15. The unit of measure shall be the cubic foot. Ninety-four (94) lb. (one (1) sack or one-fourth (¼) barrel) of cement shall be assumed as one (1) cubic foot.

Measuring Ingredients

16. The method of measurement shall be such as to secure the specified proportions in each batch. The aggregates shall be measured separately by volume or weight. In volume measurement the fine aggregate and the coarse aggregate shall be measured loose, as thrown into the measuring device, due allowance being made for bulking. The water shall be so measured as to insure the desired quantity in successive batches.

Proportioning

Water Cement Ratio

17. The water-cement ratio is essentially equivalent to the void-cement ratio.

The proportioning of materials for the class of concrete specified or shown on the plans shall be based on the requirements for a plastic and workable mix containing not more than the amount of water per sack (94 lb.) of cement for each class of concrete as follows:

Amount of Water

Class of Concrete Compression Strength Lb. per sq. in. 28 Days	*Gallons of Water Per Sack of Cement*
3500	5.00
3000	5.50
2500	6.25
2000	7.00
1500	8.00

These quantities of water must not be exceeded. Water in the aggregate must be included in the quantity specified and subtracted from the amount added to the mixture.

Moisture in Aggregate

18. Moisture in the aggregate shall be measured by methods satisfactory to the Engineer, which will give results within one pound for each 100 lb. of aggregate.

Workability

19. The mixture shall be such as to produce concrete that can be worked readily into the corners and angles of the form and around the reinforcement without excessive spading. The workability will be controlled by adding or deducting fine or coarse aggregate, but in no

case shall the amount of coarse aggregate be such as to produce harshness in placing or honeycombing in the structure.[*]

Slump

20. The slump shall be within the following limits:

	Slump	*Inches*
Type of Work	*Minimum*	*Maximum*
Massive sections	1	3
Heavy walls, slabs and beams..	2	5
Thin walls, columns, etc.	3	6
Pavements	1	3

Note.—The slump test is a relative test and serves as a guide to gage the consistency to meet the workability adopted as satisfactory for special requirements.

Tests

21. Duplicate copies of all test data taken by the contractor for the control of concrete shall be filed with the Engineer immediately after the data is obtained. The contractor shall furnish concrete for such test cylinders as the Engineer may require.

Four test cylinders shall be made for each 500 cubic yards of concrete deposited. On no job shall less than four cylinders be made.

Compression Tests

22. Specimens for compression tests shall be made and stored in accordance with the "Standard Method of Making and Storing Specimens of Concrete in the Field" (Serial Designation C 31-21) of the American Society for Testing Materials. These specimens shall be tested in accordance with "Tentative Method of Making Compression Tests of Concrete" (Serial Designation C 39-21 T), of the American Society for Testing Materials.

MIXING

Machine Mixing

23. The mixing of concrete, unless otherwise authorized by the Engineer, shall be done in a batch mixer of approved type which will insure a uniform distribution of the materials throughout the mass, so that the mixture is uniform in color and homogeneous. The mixer shall be equipped with suitable charging hopper, water storage, and a water measuring device controlled from a case which can be kept locked and so constructed that the water can be discharged only while the mixer is being charged. It shall also be equipped with an attachment for automatically locking the discharge lever until the batch has been mixed the required time after all materials are in the mixer. The entire contents of the drum shall be discharged before recharging.

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[*] That combination of fine and coarse aggregate which will produce the desired workability will vary with the grading of the aggregates. Combinations of fine and coarse aggregate within the following limits will ordinarily produce workable mixes:

- For ¾ in. maximum size of aggregate—
  - Not more than 1⅔ parts of fine to one part of coarse, and
  - Not less than ⅔ part of fine to one part of coarse.
- For 1 in. and over maximum size of aggregate—
  - Not more than 1 part of fine to one part of coarse, and
  - Not less than ½ part of fine to one part of coarse.

The mixer shall be cleaned at frequent intervals while in use. The volume of the mixed material per batch shall not exceed the manufacturer's rated capacity of the mixer.

Time of Mixing

24. The mixing of each batch shall continue not less than one minute after all the materials are in the mixer, during which time the mixer shall rotate at a peripheral speed of about 200 ft. per minute.

Hand Mixing

25. When it is permitted to mix by hand, the mixing shall be done on a watertight platform of sufficient size to accommodate men and materials for the progressive and rapid mixing of at least two batches of concrete at the same time. The batches shall not exceed one-half (½) cubic yard each. The materials shall be mixed dry until the mixture is of a uniform color, the required amount of water added, and the mixing continued until the batch is of a uniform consistency and character throughout. Hand mixing will not be permitted for concrete deposited under water.

Retempering

26. The retempering of concrete or mortar which has partially hardened, that is, remixing with or without additional cement, aggregate, or water, will not be permitted.

Depositing Concrete

Cleaning Equipment

27. Before beginning a run of concrete, hardened concrete and foreign materials shall be removed from the inner surfaces of the mixing and conveying equipment.

General

28. Before depositing any concrete, all debris shall be removed from the space to be occupied by the concrete, all steel reinforcing shall be secured in its proper location, all forms shall be thoroughly wetted except in freezing weather, unless they have been previously oiled, and all form work and steel reinforcing shall be inspected and approved by the Engineer.

Handling and Placing

29. Concrete shall be handled from the mixer to the place of final deposit as rapidly as practicable by methods which shall prevent the separation or loss of the ingredients. It shall be deposited in the forms as nearly as practicable in its final position to avoid rehandling. It shall be so deposited as to maintain, until the completion of the unit, a plastic surface approximately horizontal. Forms for walls or other thin sections of considerable height shall be provided with openings or other devices, that will permit the concrete to be placed in a manner that will avoid accumulations of hardened concrete on the forms or metal reinforcement. Under no circumstances shall concrete that has partially hardened be deposited in the work.

Chuting

30. When concrete is conveyed by chuting, the plant shall be of such size and design to as insure a practically continuous flow in the chute. The angle of the chute with the horizontal shall be such as to allow the concrete to flow without separation of the ingredients. The delivery end of the chute shall be as close as possible to the point of deposit. When the operation is intermittent, the spout shall discharge into a hopper. The chute shall be thoroughly flushed with water before and after each run; the water used for this purpose shall be discharged outside the forms.

Compacting

31. Concrete, during and immediately after depositing, shall be thoroughly compacted by means of suitable tools. For thin walls or inaccessible portion of the forms, where rodding or forking is impracticable, the concrete shall be assisted into place by tapping or hammering the forms opposite the freshly deposited concrete. The concrete shall be thoroughly worked around the reinforcement, and around embedded fixtures and into the corners of the forms.

Removal of Water

32. Water shall be removed from excavations before concrete is deposited, unless otherwise directed by the Engineer. Any flow of water into the excavation shall be diverted through proper side drains to a sump, or be removed by other approved methods which will avoid washing the freshly deposited concrete. Water vent pipes and drains shall be filled by grouting or otherwise, after the concrete has thoroughly hardened.

Protection

33. Exposed surfaces of concrete shall be protected from premature drying for a period of at least seven days after being deposited.

Temperature

34. Concrete when deposited shall have a temperature not below 50° Fahr. and not above 120° Fahr. In freezing weather suitable means shall be provided for maintaining the concrete at a temperature not lower than 50° Fahr., for not less than 72 hours after placing, or until the concrete has thoroughly hardened. The methods of heating the materials and protecting the concrete shall be approved by the Engineer. Salt, chemicals, or other foreign materials shall not be mixed with the concrete for the purpose of preventing freezing.

Continuous Depositing

35. Concrete shall be deposited continuously and as rapidly as practicable until the unit of operation, approved by the Engineer, is completed. Construction joints at points not provided for in the plans shall be made in accordance with the provisions in Section 58.

Depositing Against Other Concrete

36. Before depositing new concrete on or against concrete which has hardened, the forms shall be retightened, the surface of the hardened concrete shall be roughened as required by the Engineer, thor-

oughly cleaned of foreign matter and laitance, and saturated with water. The new concrete placed in contact with hardened or partially hardened concrete shall contain an excess of mortar to insure bond. To insure this excess mortar at the juncture of the hardened and the newly deposited concrete, the cleaned and saturated surfaces of the hardened concrete, including vertical and inclined surfaces, shall first be slushed with a coating of neat cement grout against which the new concrete shall be placed before the grout has attained its initial set.

Depositing Concrete Under Water

General

37. When the depositing of concrete under water is authorized by the Engineer, the methods, equipment and materials to be used shall be submitted to and approved by the Engineer before the work is started. Concrete shall be deposited by a method that will prevent the washing of the cement from the mixture, minimize the formation of laitance and avoid flow of water until the concrete has fully hardened. Concrete shall be placed so as to minimize segregation of materials. Concrete shall not be placed in water having a temperature below 35° Fahr.

Increasing Amount of Cement

38. Concrete to be deposited under water shall contain 1¾ bbl. (7 bags) or more of Portland cement per cubic yard of concrete in place.

Cofferdams

39. Cofferdams shall be sufficiently tight to prevent flow of water through the space in which the concrete is to be deposited. Pumping will not be permitted while concrete is being deposited, nor before it has fully hardened.

Continuous Work

40. When depositing concrete under water is permitted, concrete shall be deposited continuously, keeping the top surface as nearly level as possible, until it is brought above the water, or to the required height. The work shall be carried on with sufficient rapidity to prevent the formation of layers.

Method

41. One of the following methods of depositing concrete under water may be used:

(a) Tremie: The tremie shall be water-tight and sufficiently large to permit a free flow of concrete. It shall be kept filled[1] at all times during depositing. The concrete shall be discharged and spread by raising the tremie in such manner as to maintain as nearly as practicable a uniform flow and avoid dropping the concrete through water.

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[1] The tremie may be filled by one of the following methods: (1) Place the lower end in a box partly filled with concrete, so as to seal the bottom, then lower into position; (2) plug the tremie with cloth sacks or other material, which will be forced down as the pipe is filled with concrete: (3) plug the end of the tremie with cloth sacks filled with concrete.

If the charge is lost during depositing the tremie shall be withdrawn and refilled.

(b) Drop-Bottom Bucket: The bucket shall be of a type that cannot be dumped until it rests on the surface upon which the concrete is to be deposited. The bottom doors when tripped shall open freely downward and outward. The top of the bucket shall be open. The bucket shall be completely filled, and slowly lowered to avoid back-wash. When discharged, the bucket shall be withdrawn slowly until well above the concrete.

(c) Bags: Bags of jute or other coarse cloth shall be filled about two-thirds full of concrete and carefully placed by hand in a header-and-stretcher system so that the whole mass is interlocked.

Laitance

42. Great care shall be exercised to not disturb the concrete more than is unavoidable when it is being deposited under water in order to avoid the formation of laitance. On completing a section of concrete, the laitance shall be entirely removed before work is resumed.

FORMS

General

43. Forms shall conform to the shape, lines and dimensions of the concrete as called for on the plans. Lumber used in forms for exposed surfaces shall be dressed to a uniform thickness, and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical. For unexposed surfaces and rough work, undressed lumber may be used. Lumber once used in forms shall have nails withdrawn, and surfaces to be in contact with concrete thoroughly cleaned, before being used again.

Design

44. Forms shall be substantial and sufficiently tight to prevent leakage of mortar; they shall be properly braced or tied together so as to maintain position and shape. If adequate foundation for shores cannot be secured, trussed supports shall be provided.

Ties and Workmanship

45. Bolts and rods shall preferably be used for internal ties; they shall be so arranged that when the forms are removed no metal shall be within one inch of any surface. Wire ties will be permitted only on light and unimportant work; they shall not be used through surfaces where discoloration would be objectionable. Shores supporting successive stories shall be placed directly over those below, or so designed that the load will be transmitted directly to them. Forms shall be set to line and grade and so constructed and fastened as to produce true lines. Special care shall be used to prevent bulging.

Molding

46. Unless otherwise specified, suitable moldings or bevels shall be placed in the angles of forms to round or bevel the edges of the concrete.

Oiling Forms

47. The inside of forms shall be coated with non-staining mineral oil or other approved material or thoroughly wetted (except in freezing weather). Where oil is used, it shall be applied before the reinforcement is placed.

Temporary Openings

48. Temporary openings shall be provided at the base of column and wall forms, and at other points where necessary to facilitate cleaning and inspection immediately before depositing concrete.

Removal

49. Forms shall not be disturbed until authorized by the Engineer. Shoring shall not be removed until the member has acquired sufficient strength to safely support its weight and the load upon it. Members subject to additional loads during construction shall be adequately shored to support both the member and construction loads in such a manner as will protect the member from damage by the loads; this shoring shall not be removed until the member has acquired sufficient strength to safely support its weight and the load upon it.

Metal Reinforcement

Cleaning

50. Metal reinforcement, before being positioned, shall be thoroughly cleaned of mill and rust scale and of coatings that will destroy or reduce the bond. Reinforcement appreciably reduced in section shall be rejected. Where there is delay in depositing concrete, reinforcement shall be reinspected and, when necessary, cleaned.

Bending

51. Reinforcement shall be carefully formed to the dimensions indicated on the plans. Cold bends shall be made around a pin having a diameter of three or more times the least dimension of the reinforcement bars for steel of structural grade and six or more times that for steel of intermediate or hard grade.

Straightening

52. Metal reinforcement shall not be bent or straightened in a manner that will injure the material. Bars with kinks or bends not shown on the plans shall not be used. Heating of reinforcement will be permitted only when the entire operation is approved by the Engineer.

Placing

53. Metal reinforcement shall be accurately positioned, and secured against displacement by using annealed iron wire of not less than No. 18 gage or suitable clips at intersections, and shall be supported by concrete or metal chairs or spacers, or metal hangers, unless otherwise shown on the plans. The minimum clear distance between parallel bars shall be 1½ times the diameter of round bars or 1½ times the diagonal of square bars, and bars parallel to the face of

any member shall be embedded a clear distance of not less than one inch from the face.

Splicing

54. Wherever it is necessary to splice the reinforcement otherwise than as shown on the plans, the character of the splice shall be decided by the Engineer on the basis of safe bond stress and the stress in the reinforcement at the point of splice. Splices shall not be made at points of maximum stress nor shall adjacent bars be spliced at the same point.

Splices in columns, piers and struts shall provide sufficient lap to transfer the stress by bond.

Future Bonding

55. Exposed reinforcement bars intended for bonding with future extensions shall be protected from corrosion.

PROTECTIVE CONCRETE COVERING

Moisture Protection

56. Metal reinforcement in wall footings and column footings shall have a minimum covering of three inches of concrete. At surfaces of concrete exposed to the weather, metal reinforcement shall be protected by not less than two inches of concrete.

JOINTS

General

57. Instructions given on the plans, in the detailed specifications or schedule governing the work as to location and construction of joints, shall be strictly followed.

When the structures or portions of the structures are designed to be monolithic, they shall be cast integrally, except as hereinafter modified.

Construction Joints

58. (a) When necessary to provide construction joints not indicated or specified, such joints shall be located and formed so as to not impair the strength and to least impair the appearance of the structure. Where conditions require, the joints shall be reinforced as directed by the Engineer in order to secure the necessary bond strength. Horizontal construction joints shall be prepared at the time the work is interrupted by thoroughly roughening the surface and providing keys or mortises, or by means of steel dowels set substantially at right angles to the plane of the joint.

(b) To prevent laitance in horizontal joints, excess water shall be removed from the surface forming the joint after depositing the concrete. Surfaces of contact shall be cleaned and wetted before depositing is resumed, and any laitance shall be removed.

(c) Where girders, beams and slabs are designed to be monolithic with walls and columns they shall not be cast until four hours after completion of the walls or columns in order to permit of shrinkage or settlement. In case the columns are structural steel incased in concrete, the lapse of time to allow for shrinkage or settlement need not be observed.

Joints in Columns

59. Joints in columns shall be made at the underside of the floor. Haunches and column capitals shall be considered as part of and to act continuous with the floor. At least two hours must elapse after depositing concrete in the columns or walls before depositing in beams, girders or slabs.

Joints in Floors

60. Construction joints in floors shall be located near the middle of spans of slabs, beams or girders, unless a beam intersects a girder at this point, in which case the joints in the girders shall be offset a distance equal to twice the width of the beam. Adequate provision shall be made for shear by use of inclined reinforcement.

Expansion Joints

61. At all expansion joints, the structure adjacent to the joint shall preferably be supported on separate columns or walls. Reinforcement shall not extend across an expansion joint; the break between the two sections shall be complete. Exposed edges of expansion joints in walls or abutments shall be rounded. Exposed expansion joints between two distinct concrete members shall be filled with an elastic joint filler of approved quality.

Sliding Joints

62. The seat of sliding joints shall be finished to a smooth plane surface and allowed to harden.

Water-tight Construction Joints

63. Where construction joints are required to be water-tight the method of construction shall be as follows:

(a) Horizontal joints shall be constructed by forming a continuous keyway in the lower portion of concrete before the concrete has hardened. Before placing the superimposed concrete the joint shall be thoroughly cleaned of laitance or other foreign material, saturated with water and coated with neat cement grout. The superimposed concrete shall be placed in such a manner as will insure an excess of mortar over the entire surface of the joint.

(b) Vertical joints shall be made by a non-corrosive metal water-stop approved by the Engineer.

Waterproofing

General

64. Concrete required to be water-tight shall be made with strict adherence to all provisions in these specifications regarding the choice of materials, proportions, consistency, mixing, placing, protection, and workmanship.

Types

65. (a) For Specifications for Membrane Waterproofing on Solid Floor Railway Bridges, see under Iron and Steel Structures.

(b) Integral compounds shall not be used for waterproofing unless specifically authorized by the Engineer.

CONCRETE IN SEA WATER

Proportions

66. Plain concrete in sea water from 2 ft. below low water to 2 ft. above high water, or from a plane below to a plane above wave action, shall contain a minimum of 1¾ bbl. (7 bags) of Portland cement per cubic yard in place. Other plain concrete in sea water or exposed directly along the sea coast shall contain a minimum of 1½ bbl. (6 bags) of Portland cement per cubic yard in place. Porous or weak aggregates shall not be used.

Depositing in Sea Water

67. Sea water shall not be allowed to come in contact with the concrete until it has hardened for at least four days. Concrete shall be placed in such a manner as to minimize the number of horizontal or inclined seams or work planes. The placing of concrete between tides shall be, so far as possible, a continuous operation. Concrete shall be deposited in sea water only when so directed by the Engineer.

Protecting Concrete in Sea Water

68. In concrete exposed to sea water the metal reinforcement shall be placed not less than three inches from any plane or curved surface, and at corners it shall be not less than four inches from adjacent surfaces. Metal chair supports or ties shall not extend to the surface of the concrete. Where severe climatic conditions or severe abrasions are anticipated, the face of the concrete from two feet below low water to two feet above high water, or from a plane below to a plane above wave action shall be protected by stone of suitable quality, dense vitrified shale brick as designated on the plans or as required by the Engineer, or in special cases the protection may be creosoted timber.

CONCRETE IN ALKALI SOILS OR WATERS

Proportions

69. Concrete in alkali waters or below ground-line of alkali soils shall contain a minimum of 1¾ bbl. (7 bags) of Portland cement per cubic yard in place.

Placing

70. Concrete in alkali soils or waters shall be placed in such a manner as to minimize the number of horizontal or inclined seams, or work planes.

Protection

71. Metal reinforcement or other corrodible metal shall not be placed closer than two inches to the surface of members exposed to

alkali soils or waters. In foundations and in heavy structures the metal reinforcement shall not be placed closer than three inches to the surface.

SURFACE FINISH

General

72. (a) The requirements in these specifications applying to forms, mixing, conveying and depositing concrete shall be followed unless modified by the plans or by the direction of the Engineer.

(b) The whole of an exposed surface between prescribed construction limits shall be cast in one continuous operation. Construction and expansion joints, when not shown on the plans, shall be made as directed by the Engineer, and shall be true to line with sharp unbroken edges.

(c) The same brand of cement and the same kind and size of aggregate shall be used throughout the whole of any exposed surface.

(d) For exposed surfaces the forms shall be smooth and water-tight. If of wood the boards shall be planed to a uniform thickness evenly matched with tongue and groove and tightly placed. They shall be so constructed that they can be removed without hammering or prying against the concrete. All offsets or mismatching of the boards shall be dressed to a smooth surface and all openings and cracks pointed flush with clay or plaster of Paris, to prevent leakage and the formation of fins.

(e) The concrete for exposed surfaces shall be so mixed, placed and worked with a spading tool, that the aggregate is uniformly distributed and a full surface of mortar brought against the form, free from air pockets and void spaces. If the finish is to be one that will expose the coarse aggregate, by either scrubbing, tooling, sand-blasting or acid treatment, then after the full surface of mortar has been worked against the form, the coarse aggregate shall be spaded against the form, to secure a uniform distribution at the face and a uniform texture of the exposed aggregate in the finished surface.

(f) The forms shall be removed from exposed surfaces as soon as the proper setting of the cement will permit, all fins and other projections carefully removed and offsets leveled; all voids and damaged places shall be immediately saturated with water, filled with a mixture of the same composition as the concrete and smoothed even with the surface with a wooden float or spatula. A steel trowel shall not be used for this purpose. Plastering and brush coating will not be permitted. The surface shall be finished free from streaks, discolorations and other imperfections.

(g) Whenever the forms are removed before the concrete has properly set, the surface shall be immediately wetted and kept wet for not less than three days.

Top Surfaces Not Subject to Wear

73. Top surfaces not subject to wear shall be smoothed with a wood float and be kept wet for at least seven days. Care shall be taken to avoid an excess of water in the concrete, and to drain or otherwise promptly remove any water that comes to the surface. Dry

cement, or a dry mixture of cement and sand, shall not be sprinkled directly on the surface.

WEARING SURFACE FINISH

One-Course Work

74. Aggregates for the wearing surface in one-course work shall have a high resistance to abrasion, and shall be screened and when necessary thoroughly washed. The least quantity of mixing water that will produce a dense concrete shall be used. The mix shall not be leaner than one part of Portland cement and 2½ parts of aggregate. The surface shall be screeded even and finished with a wooden float. Excess water shall be promptly drained or otherwise removed. Overtroweling shall be avoided.

Two-Course Work

75. The wearing surface in two-course work shall be placed within one-half hour after the base course. Where the wearing surface is required to be applied to a hardened base course, the latter shall be prepared by roughening with a pick or other effective tool. The roughened surface shall be thoroughly saturated with water and covered with a thin layer of neat cement paste immediately before the wearing surface is placed. The wearing course shall not be thinner than one inch.

Curing

76. Concrete wearing surfaces of roads and pavement made in accordance with Sections 74 and 75, shall be kept wet for at least 21 days.

DECORATIVE FINISHES

Rubbed Finish

77. Immediately after the forms are removed and all voids filled, the surface shall be thoroughly wetted and rubbed with a carborundum brick, or other abrasive, to a smooth, even finish of uniform appearance without applying any cement or other coating.

Scrubbed Finish

78. The forms shall be removed while the concrete is still green and the surface scrubbed with stiff fiber or wire brushes, using water freely, until the aggregate is uniformly exposed to the desired extent. The whole surface shall then be thoroughly washed with clean water. If portions of the surface have become too hard to scrub to equal relief, or the film of cement is not removed from the surface of the exposed aggregate, diluted hydrochloric acid (1 part acid to 4 parts water) may be used to facilitate the scrubbing. All traces of the acid shall be thoroughly removed with clean water.

Sand-Blast Finish

79. In preparing the surface for a sand-blast finish, the concrete face shall be permitted to attain an intermediate degree of hardness; it shall then be air-blasted with hard sand until the aggregate is in uniform relief.

Tooled Finish

80. The surface shall first be permitted to become dry and hard, and then dressed with tools, as called for, to a uniform texture and even face.

Sand Floated Finish

81. The form shall be removed before the surface has fully hardened; the surface shall be rubbed with a wooden float by a uniform circular motion, fine sand being rubbed into the surface until the resulting finish is even and uniform.

Acid Treated Finish

82. After the forms are removed and all voids filled, the surface shall be washed with commercial hydrochloric or nitric acid, diluted with water to a strength such that the bonding of the cement is not broken beyond the required depth. The solution shall be applied with stiff vegetable fiber brushes and the surface scrubbed until the aggregate is exposed to the desired extent. All traces of the acid shall then be quickly and completely washed off with water to prevent further action and the permanent discoloration of the surface.

Colored Pigment Finish

83. Mineral pigment when used shall be thoroughly mixed dry with the cement and fine aggregate; care shall be taken to secure a uniform tint throughout.

(IV) DESIGN

Note.—For diagrams and figures, see Appendix A, page 644.

General Assumptions

84. The design of reinforced concrete members under these specifications shall be based on the following assumptions:

(a) Calculations are made with reference to working stresses and safe loads rather than with reference to ultimate strength and ultimate loads.

(b) A plane section before bending remains plane after bending, shearing distortions being neglected.

(c) The modulus of elasticity of concrete in compression is constant within the limits of working stresses and the distribution of compressive stress in beams is rectilinear.

(d) The moduli of elasticity of concrete in computations for the position of the neutral axis, for the resisting moment of beams, and for compression of concrete in columns, are as follows:

(1) $\frac{1}{15}$ that of steel, when the compressive strength of the concrete at 28 days exceeds 1500 and does not exceed 2200 lb. per sq. in.;

(2) $\frac{1}{12}$ that of steel, when the compressive strength of the concrete at 28 days exceeds 2200 and does not exceed 2900 lb. per sq. in.;

(3) $\frac{1}{10}$ that of steel, when the compressive strength of the concrete at 28 days is greater than 2900 lb. per sq. in.

(e) In calculating the moment of resistance of reinforced concrete beams and slabs the tensile resistance of the concrete is neglected.

(f) The bond between the concrete and the metal reinforcement remains unbroken throughout the range of working stresses. Under compression the two materials are therefore stressed in proportion to their moduli of elasticity.

(g) Initial stress in the reinforcement due to contraction or expansion of the concrete is neglected, except in the design of reinforced concrete columns.

FLEXURE OF RECTANGULAR REINFORCED CONCRETE BEAMS AND SLABS

Flexure Formulas

85. Computations of flexure in rectangular reinforced concrete beams and slabs shall be based on the following formulas:

(a) Reinforced for tention only.

Position of neutral axis,

$$k = \sqrt{2pn + (pn)^2} - pn \quad \dots\dots (1)$$

Arm of resisting couple,

$$j = 1 - \frac{k}{3} \quad \dots\dots (2)$$

Compressive unit stress* in extreme fiber of concrete,

$$f_c = \frac{2M}{jkbd^2} = \frac{2pf_s}{k} \quad \dots\dots (3)$$

Tensile unit stress* in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} = \frac{M}{pjbd^2} \quad \dots\dots (4)$$

Steel ratio for balanced reinforcement,

$$p = \tfrac{1}{2} \frac{1}{\dfrac{f_c}{f_s}\left(\dfrac{f_s}{nf_c} + 1\right)} \quad \dots\dots (5)$$

(b) Reinforced for both tension and compression.

Position of neutral axis,

$$k = \sqrt{2n\left(p + p'\frac{d'}{d}\right) + n^2 (p + p')^2} - n(p + p') \quad \dots\dots (6)$$

Position of resultant compression,

$$z = \frac{\dfrac{1}{3}k^3d + 2p'nd'\left(k - \dfrac{d'}{d}\right)}{k^2 + 2p'n\left(k - \dfrac{d'}{d}\right)} \quad \dots\dots (7)$$

Arm of resisting couple, (*)

$$jd = d - z \quad \dots\dots (8)$$

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*For $fs = 16{,}000$ to 18,000 lb. per sq. in. and $fc = 800$ to 900 lb. per sq. in., j may be assumed as 0.86. For values of pn varying from 0.04 to 0.24 jk is approximately equal to $0.67 \sqrt[3]{pn}$.

Compressive unit stress in extreme fiber of concrete,

$$f_c = \frac{6M}{bd^2\left[3k - k^2 + \frac{6p'n}{k}\left(k - \frac{d'}{d}\right)\left(1 - \frac{d'}{d}\right)\right]} \qquad \ldots\ldots(9)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{pjbd^2} = nf_c\frac{1-k}{k} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

Compressive unit stress in longitudinal reinforcement,

$$f'_s = nf_c\frac{k - \frac{d'}{d}}{k} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

Notation

86. The symbols used in the following formulas are defined as follows:

A_s = effective cross-sectional area of metal reinforcement in tension in beams;

b = width of rectangular beam or width of flange of T-beam;

d = depth from compression surface of beam or slab to center of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to center of compression reinforcement;

f_c = compressive unit stress in extreme fiber of concrete;

f_s = tensile unit stress in longitudinal reinforcement;

f'_s = compressive unit stress in longitudinal reinforcement;

I = moment of inertia of a section about the neutral axis for bending;

j = ratio of lever arm of resisting couple to depth d;

k = ratio of depth of neutral axis to depth d;

l = span length of beam or slab (generally distance from center to center of supports);

L = distance between lateral supports.

M = bending moment or moment of resistance in general;

$n = E_s/E_c$ = ratio of modulus of elasticity of steel to that of concrete;

p = ratio of effective area of tension reinforcement to effective area of concrete in beams $= A_s/bd$;

p' = ratio of effective area of compression reinforcement to effective area of concrete in beams;

w = uniformly distributed load per unit of length of beam or slab;

z = depth from compression surface of beam or slab of resultant of compressive stresses.

Span Length

87. The span length, l, of freely supported beams and slabs, shall be the distance between centers of the supports (required bearing area), but shall not exceed the clear span plus the depth of beam or slab. The span length for continuous or restrained beams built to act integrally with supports shall be the clear distance between faces of supports. Where brackets having a width not less than the width of the beam and making an angle of 45 deg. or more with the horizontal axis of a restrained beam are built to act integrally with the beam and support, the span shall be measured from

the section where the combined depth of the beam and bracket is at least one-third more than the depth of the beam, but no portion of such a bracket shall be considered as adding to the effective depth of the beam. Maximum negative moments are to be considered as existing at the ends of the span as defined above.

Slightly Restrained Beams of Equal Span

88. Beams and slabs of equal spans built to act integrally with beams, girders, or other slightly restraining supports and carrying uniformly distributed loads shall be designed for the following moments at critical sections:

(a) Beams and slabs of one span,
Maximum positive moment near center,

$$M = \frac{wl^2}{8} \quad \dots\dots (12)$$

(b) Beams and slabs continuous for two spans only,

(1) Maximum positive moment near center,

$$M = \frac{wl^2}{10} \quad \dots\dots (13)$$

(2) Negative moment over interior support,

$$M = \frac{8}{wl^2} \quad \dots\dots (14)$$

(c) Beams and slabs continuous for more than two spans,

(1) Maximum positive moment near center and negative moment at support of interior spans,

$$M = \frac{wl^2}{12} \quad \dots\dots (15)$$

(2) Maximum positive moment near centers of end spans and negative moment at first interior support,

$$M = \frac{wl^2}{10} \quad \dots\dots (16)$$

(d) Negative moment at end supports for cases (a), (b), (c), of this section,

$$M = \text{not less than } \frac{wl^2}{16} \quad \dots\dots (17)$$

Beams Built Into Brick or Masonry Walls

89. Beams and slabs built into brick or masonry walls in a manner which develops partial end restraint shall be designed for a negative moment at the support of

$$M = \text{not less than } \frac{wl^2}{16} \quad \dots\dots (18)$$

Freely Supported Beams of Equal Span

90. Beams and slabs of equal spans freely supported and assumed to carry uniformly distributed loads shall be designed for the moments speci-

fied, except that no reinforcement for negative moment need be provided at end supports where effective measures are taken to prevent end restraint. The span shall be taken as defined for freely supported beams.

Restrained Beams of Equal Span

91. Beams and slabs of equal span built to act integrally with columns, walls, or other restraining supports and assumed to carry uniformly distributed loads, shall be designed for the following moments at critical sections:

(a) Interior spans,

(1) Negative moment at interior supports except the first,

$$M = \frac{wl^2}{12} \qquad (19)$$

(2) Maximum positive moment near centers of interior spans,

$$M = \frac{wl^2}{16} \qquad (20)$$

(b) End spans of continuous beams and beams of one span in which I/l is less than twice the sum of the values of I/h for the exterior columns above and below which are built into the beams:

(1) Maximum positive moment near center of span and negative moment at first interior supports,

$$M = \frac{wl^2}{12} \qquad (21)$$

(2) Negative moment at exterior supports,

$$M = \frac{wl^2}{12} \qquad (22)$$

(c) End spans of continuous beams, and beams of one span, in which I/l is equal to or greater than twice the sum of the values of I/h for the exterior column above and below which are built into the beams:

(1) Maximum positive moment near center of span and negative moment at first interior support,

$$M = \frac{wl^2}{10} \qquad (23)$$

(2) Negative moment at exterior support,

$$M = \frac{wl^2}{16} \qquad (24)$$

Continuous Beams of Unequal Spans or with Non-Uniform Loading

92. Continuous beams with unequal spans, or with other than uniformly distributed loading, whether freely-supported or restrained shall be designed for the actual moments under the conditions of loading and restraint.

Provision shall be made where necessary for negative moment near the center of short spans which are adjacent to long spans, and for the negative moment at the end supports, if restrained.

Unsupported Length

93. The distance between lateral supports of the compression area of a rectangular beam shall not exceed 24 times the least width of the beam.

Compressive Stress in Beams

94. The allowable compressive stress in a rectangular beam shall not exceed

$$f_c\ (1.2 - \frac{L}{50b}) \quad (L \text{ shall not be greater than } f_c.)$$

[1]FLEXURE OF REINFORCED CONCRETE T-BEAMS

Flexure Formulas

95. Computations of flexture in reinforced concrete T-beams shall be based on the following formulas:

(a) Neutral Axis in the Flange.
Use formulas for rectangular beams and slabs in Section 85.

(b) Neutral Axis below the Flange.
Position of neutral axis,

$$kd = \frac{2nd\,A_s + bt^2}{2nA_s + 2bt} \qquad \text{(25)}$$

Position of resultant of compressive stresses,

$$z = \left(\frac{3kd - 2t}{2kd - t}\right)\frac{t}{3} \qquad \text{(26)}$$

Arm of resisting couple,

$$jd = d - z \qquad \text{(27)}$$

Compressive unit stress in extreme fiber of concrete,

$$f_c = \frac{Mkd}{bt\,(kd - \frac{1}{2}t)\,jd} = \frac{f_s}{n}\left(\frac{k}{1-k}\right) \qquad \text{(28)}$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} \qquad \text{(29)}$$

The above formulas neglect compression in the web below the bottom of flange. See footnote for exact formulas where thickness of the flange is small as compared with the depth of the web.*

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*Position of neutral axis,

$$kd = \sqrt{\frac{2ndA_s + (b-b')\,t^2}{b'} + \left(\frac{nA_s + (b-b')\,t}{b'}\right)^2} - \left(\frac{nA_s + (b-b')\,t}{b'}\right) \qquad \text{(25a)}$$

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[1] Adopted, Vol. 29, 1928, pp. 607, 1399.

Position of resultant of compressive stresses,

$$z = \frac{(kdt^2 - \tfrac{2}{3}t^3)\ b + [((kd - t)^2\ (t + \tfrac{1}{3}\ (kd - t))]b'}{t\ (2kd - t)\ b + (kd - t)^2b'} \quad \ldots\ldots (26a)$$

Arm of resisting couple,

$$jd = d - z \quad \ldots\ldots (27a)$$

Compressive unit stress in extreme fiber of concrete,

$$f_c = \frac{2\,Mkd}{((2kd - t)\ bt + (kd - t)^2b')\ jd} \quad \ldots\ldots (28a)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} \quad \ldots\ldots (29a)$$

Notation

96. The symbols used in T-Beam formulas are as defined in Section 86 together with the following:

b' = width of web of T-Beam.
t = thickness of flange of T-Beam.

General

97. The slab forming the flange of the T-Beam shall be designed and constructed as an integral part of the beam. Effective and adequate bond and shear resistance shall be provided in beam and slab construction at the junction of the web of the T-Beam and the slab.

Flange Width and Thickness

98. (a) For symmetrical T-Beams in slab and beam construction the effective flange width to be used in the design shall not exceed one-fourth the span length of the beam, nor shall the overhanging flange width on either side of the web exceed six times the flange thickness or one-half the clear distance between faces of the adjacent T-Beam webs.

(b) For T-Beams having a flange on one side only, the effective flange width to be used in the design shall not exceed one-tenth of the span length of the beam, nor shall the overhanging flange width beyond the face of the web exceed four times the flange thickness or one-half the distance from the face of its web to that of the adjacent T-Beam.

(c) Isolated beams, in which the tee form is used only for the purpose of providing additional compression area, shall have a flange thickness not less than one-half the web width and a total flange width not more than three times the web width. The distance between lateral supports shall not exceed sixteen times the least width of the compression flange. The allowable compressive stress in the flange shall not exceed $f_c \left(1.2 - \frac{L}{30b}\right)$ but in no case shall it exceed f_c.

Transverse Reinforcement

99. The area of steel near the upper face of the flange of T-Beam effective as transverse reinforcement shall be not less than 0.3 of one per

cent of section of the slab and shall extend, not less than one-quarter of the span into the slab, each side of the axis of the T-Beam. The spacing of bars shall not be greater than three times the effective depth of slab nor more than 18 in.

Compressive Stress at Supports of Continuous T-Beams

100. Provision shall be made for the compressive stress at the support in continuous T-Beam construction, considering the web section as a rectangular beam with both tensile and compressive reinforcement.

Shear

101. The flange overhang of T-Beams shall not be considered as effective in computing the resistance of the beam to horizontal and vertical shears or the diagonal tension resistance of the beam.

DIAGONAL TENSION AND SHEAR

Notation

102. The symbols used in the following formulas are defined in Section 86, except as follows:

A_v = total area of web reinforcement in tension within a distance s, that is, S_1, S_2, S_3, . . . Sn, or the total area of all bars bent up in any one plane;

α = angle between web bars and longitudinal bars;

F = total tension in a bar;

f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12 in. or 8 by 16-in. cylinders made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field and the Tentative Methods of Making Compression Tests of Concrete;

f_v = tensile unit stress in web reinforcement;

Q = ratio of the average to the maximum bond stress within the distance y;

Σ_o = sum of perimeters of bars in one set;

r = ratio of cross-sectional area of negative reinforcement which crosses entirely over the column capital of a flat slab or over the dropped panel, to the total cross-sectional area of the negative reinforcement in the two column strips;

s = spacing of web bars or stirrups measured at the plane of the lower reinforcement and in the direction of the longitudinal axis of the beam;

t_1 = thickness of flat slab without dropped panels or thickness of a dropped panel;

t_2 = thickness of flat slab with dropped panels at points away from the dropped panel;

u = bond stress per unit of area of surface of bar;

v = shearing unit stress;

V = total shear;

x = length of bar added for anchorage, including the hook, if any;

y = distance from the point at which tension is computed to the point of beginning of anchorage.

Formula for Shear

103. The shearing unit-stress, v, in reinforced concrete beams shall be taken as not less than that computed by the formula

$$v = \frac{V}{bjd} \quad \ldots\ldots (30)$$

Variation of Shear in Beams with Uniform Load

104. For purpose of design of beams carrying uniform loads, not less than one-fourth of the total shearing resistance required at either end of span shall be provided at the section where the computed shearing stress is zero; from that section to the ends of span the required shearing resistance shall be assumed to vary uniformly.

Width of Beams in Shear Computations

105. The shearing unit stress shall be computed on the minimum width of rectangular beams and on the minimum thickness of the web in beams of I or T-section.

Types of Spacing of Web Reinforcement

106. Web reinforcement may consist of:

(a) Vertical stirrups or web reinforcing bars;
(b) Inclined stirrups or web reinforcing bars forming an angle of 30 deg. or more with the longitudinal bars;
(c) Longitudinal bars bent up at an angle of 15 deg. or more with the direction of the longitudinal bars.

Stirrups or bent-up bars to be considered as web reinforcement must be anchored at both ends, as specified in Section 119. When the shearing stress is not greater than $0.06\, f'_c$, the distance S measured in the direction of the axis of the beam between two successive stirrups, or between two successive points of bending up of bars or from the point of bending up of a bar to the edge of the support, shall not be greater than

$$S = \frac{45_d}{\alpha + 10} \quad \ldots\ldots (31)$$

where the angle α is in degrees.

When the shearing stress is greater than $0.06 f'_c$, the distance S shall not be graeter than two-thirds of the values given by the above formula.

Beams Without Special Anchorage of Longitudinal Reinforcement

107. The shearing unit stress computed by formula in Section 103 in beams in which the longitudinal reinforcement is without special anchorage shall not exceed the values given by the following formulas and in no case shall it exceed $0.06 f'_c$.

When α is between 45 and 90 deg.,

$$v = 0.02\, f'_c + \frac{f_v A_v}{bs \sin \alpha} \quad \ldots\ldots (32)$$

When α is less than 45 deg.,

$$v = 0.02\, f'_c + \frac{f_v A_v}{bs} (\sin \alpha + \cos \alpha) \ldots\ldots (33)$$

Beams With Special Anchorage of Longitudinal Reinforcement

108. The shearing unit stress computed by the formula in Section 103 in beams in which longitudinal reinforcement is anchored by means of hooked ends or otherwise, as specified in Section 119, shall not exceed the value given by formulas in Section 107, when $0.03 f'_c$ is substituted for $0.02 f'_c$ in those formulas; in no case shall the shearing unit stress exceed $0.075 f'_c$.

Beams With Bars Bent Up at a Single Point

109. Where the web reinforcement consists of bars bent up at a single point, the point of bending shall be at a distance s from the edge of the support, not greater than that given in Section 99 and the value of the quantity $\frac{f_v A_v}{bs} (\sin \alpha + \cos \alpha)$ used in the design shall not exceed 75 lb. per sq. in.

Combined Web Reinforcement

110. Where two or more types of web reinforcement are used in conjunction, the total shearing resistance of the beam shall be assumed as the sum of the shearing resistances computed for the various types separately. In such computations the shearing resistance of the concrete (the term $0.02 f'_c$ or $0.03 f'_c$ in formulas in Section 107) shall be included only once. In no case shall the maximum shearing stresses be greater than the limiting values given in Sections 107 and 108.

Shear and Diagonal Tension in Footings

111. The shearing stress shall be taken as not less than that computed by the formula in Section 103. The stress on the critical section shall not exceed $0.02 f'_c$ for footings with straight reinforcement bars, nor $0.03 f'_c$ for footings in which the reinforcement bars are anchored at both ends by adequate hooks or otherwise, as specified in Section 119.

Critical Section for Soil Footings

112. The critical section for diagonal tension in footings on soil shall be computed on a vertical section through the perimenter of the lower base of a frustum of a cone or pyramid which has a base angle of 45 deg., and which has for its top the base of the column or pedestal and for its lower base the plane at the centroid of longitudinal reinforcement.

Critical Section for Pile Footings

113. The critical section for diagonal tension in footings on piles shall be computed on a vertical section at the inner edge of the first row of piles entirely outside a section midway between the face of the column or pedestal and the section described in section above for soil footings, but in no case outside the section described. The critical section for piles not arranged in rows shall be taken midway between the face of the column and the perimeter of the base of the frustum described.

BOND AND ANCHORAGE

Bond Stresses by Beam Action

114. Where bar reinforcement is used to resist tensile stresses developed by beam action, the bond stress shall be taken as not less than that computed by the formula

$$u = \frac{V}{\Sigma_o jd} \quad \ldots\ldots\ldots\ldots\ldots\ldots (34)$$

For continuous or restrained members, the critical section for bond for the positive reinforcement shall be assumed to be at the point of inflection; that for the negative reinforcement shall be assumed to be at the face of the support, and at the point of inflection. For simple beams or freely supported end spans of continuous beams, the critical section for bond shall be assumed to be at the face of the support.

Bent-up longitudinal bars which, at the critical section, are within a distance $\frac{d}{3}$ from horizontal reinforcement under consideration, may be included with the straight bars in computing Σ_o.

In footings only the bars specified in Section 131 as effective in resisting bending moment shall be considered as resisting bond stresses. Special investigation shall be made of bond stresses in footings with stepped or sloping upper surface, as maximum bond stresses may occur at the vertical plane of the steps or near the edges of the footings.

115. In beams where the ordinary anchorage described in Section 118 is provided, the bond stress computed by the formula in Section 114 at any section shall not exceed the following values:

For plain bars .... $u = 0.04\,f'_c$
For deformed bars .... $u = 0.05\,f'_c$

Bond Stresses for Special Anchorage

116. In beams where special anchorage of the bars is provided as specified in Section 119, bond stresses exceeding those specified in Section 115 may be used, provided the total tensile stress at a point of abrupt change in stress or at the point of maximum stress, does not exceed the value of F given by the formula

$$F = Qu\Sigma_o y + u\Sigma_o x \quad \ldots\ldots\ldots\ldots\ldots\ldots (35)$$

where F = total tension in the bars;
Σ_o = the perimeter of the bar under consideration;
Q = ratio of the average to the maximum bond stress computed by formula in Section 114 within the distance y.
u = permissible bond stress $= 0.04f'_c$ for plain and $0.05f'_c$ for deformed bars;
x = the length of bar added for anchorage, including the hook, if any;
y = distance from the point at which the tension is computed to the point of beginning of anchorage.

The length of bar added for anchorage may be either straight or bent. The radius of bend shall not be less than four bar diameters.

Bond Stress for Reinforcement in Two or More Directions

117. The permissible bond stress for footings and similar members in which reinforcement is placed in more than one direction shall not exceed 75 per cent of the values in Sections 115 and 116.

Ordinary Anchorage Requirements

118. In continuous, restrained or cantilever beams, anchorage of the tensile negative reinforcement beyond the face of the support shall provide for the full maximum tension with bond stresses not greater than those specified in Section 115. Such anchorage shall provide a length of bar not less than the depth of the beam. In the case of end supports which have a width less than three-fourths of the depth of the beam, the bars shall be bent down toward the support for a distance not less than the effective depth of the beam. The portion of the bar so bent down shall be as near to the end of the beam as protective covering permits. In continuous or restrained beams, negative reinforcement shall be carried to or beyond the point of inflection. Not less than one-fourth of the area of the positive reinforcement shall extend into the support to provide an embedment of ten or more bar diameters.

In simple beams or freely supported end spans of continuous beams at least one-fourth of the area of the tensile reinforcement shall extend along the tension side of the beam and beyond the face of the support to provide an embedment of ten or more bar diameters.

Special Anchorage Requirements

119. Where increased shearing stresses are used as provided in Sections 108 and 111 or increased bond stresses as provided in Section 116, special anchorage of all reinforcement in addition to that required in Section 118 shall be provided as follows:

(a) In continuous and restrained beams, anchorage beyond points of inflection of one-third the area of the negative reinforcement and beyond the face of the support of one-third the area of the positive reinforcement, shall be provided to develop one-third of the maximum working stress in tension, with bond stresses not greater than those specified in Section 115.

(b) At the edges of footings anchorage for all the bars for one-third the maximum working stress in tension shall be provided within a region where the tension in the concrete, computed as an unreinforced beam, does not exceed 40 lb. per sq. in.

(c) In simple beams or freely supported end spans of continuous beams, at least one-half of the tensile reinforcement shall extend along the tension side of the beam to provide an anchorage beyond the face of the support for one-third of the maximum working stress in tension.

Anchorage of Web Reinforcement

120. Web bars shall be anchored at both ends by:

(a) Providing continuity with the longitudinal reinforcement; or
(b) Bending around the longitudinal bar; or
(c) A semi-circular hook which has a radius not less than four times the diameter of the web bar.

Stirrup anchorage shall be so provided in the compression and tension regions of a beam as to permit the development of safe working tensile stress in the stirrup at a point 0.3d from either face.

The end anchorage of a web member not in bearing on the longitudinal reinforcement shall be such as to engage an amount of concrete sufficient to prevent the bar from pulling out. In all cases the stirrups shall be carried as close to the upper and lower surfaces as fireproofing requirements permit.

COLUMNS[4]

Limiting Dimensions

121. Unless designed as long columns, under the provisions of Section 126, reinforced concrete columns shall not be longer than twelve times the least lateral dimension. Continuous columns shall have a minimum diameter or thickness of 12 inches. Non-continuous columns shall have a minimum diameter or thickness of 6 inches.

Unsupported Length of Columns

122. The unsupported length of reinforced concrete columns shall be taken as:

(a) In flat-slab construction the clear distance between the floor and under side of the column capital.

(b) In beam-and-slab construction, the clear distance between the floor and the under side of the shallowest beam framing into the column at the next higher floor level.

(c) In floor construction with beams in one direction only, the clear distance between floor slabs.

(d) In columns supported laterally by struts or beams only, the clear distance between consecutive pairs (or groups) of struts or beams, provided that to be considered an adequate support two such struts or beams shall meet the column at approximately the same level and the angle between the two planes formed by the axis of the column and the axis of each strut respectively is not less than 75 deg. nor more than 105 deg.

(e) When reinforced concrete brackets are used at the junction of beams or struts with columns the clear distance between supports may be considered as reduced by the depth of the bracket, provided the width of the bracket is at least equal to that of the beam and not less than one-half the column.

Design of Spiral Columns

123. (a) The permissible axial load on columns reinforced with longitudinal bars and closely spaced spirals enclosing a circular core shall not be greater than that determined by formula (36):

$$P = A_c\,[1 + (n - 1)\,p]\,f_c \qquad (36)$$

in which A_c is the area within the outer circumference of the spiral hooping, and the values of f_c, as found by the formula,

$$f_c = (.25 + 12\,p')\,f'_c \qquad (37)$$

in which, $f'_c =$ the ultimate compressive strength of the concrete in 28 days, and p' is the ratio of the volume of spiral reinforcement to the volume of the column core, and p is the ratio of the effective area of longitudinal reinforcement to the area of the concrete core.

(b) The longitudinal reinforcement shall consist of at least six bars of minimum diameter of ½ inch, and of an effective cross-sectional area not less than 0.01, nor more than 0.06 of that of the core. The number of longitudinal bars concentrated in the ring at the periphery of the core shall be governed by the spacing requirements of Section 53. When the ratio of reinforcement in a spirally reinforced column is such as to require two rings of bars, special drawings illustrating the proper distribution of steel shall be shown on the detail plans. Splices in longitudinal reinforcement shall occur only where the column is laterally supported and shall provide sufficient lap to transmit the stress by bond, but not less than 24-bar diameter for deformed bars, and 30 diameters for plain bars.

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[4] Adopted, Vol. 30, 1929, pp. 783, 1461.

(c) The ratio of the spiral reinforcement to the core shall be not less than .005 nor less than one-fourth the volume of the longitudinal reinforcement. Spiral reinforcement shall conform to the provisions of Section 14 of these specifications. The pitch of the spirals shall not be greater than one-sixth of the diameter of the core and in no case more than 3 inches.

(d) Reinforcement shall be protected everywhere by a covering of concrete cast monolithic with the core and which shall have a minimum thickness of 1½ inches.

Design of Columns with Lateral Ties

124. (a) The permissible axial load on columns reinforced with longitudinal bars and separate lateral ties shall be not greater than that determined by formula (38):

$$P = A'_c\,[1 + (n - 1)\,p]\,.25\,f'_c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (38)$$

where A'_c = the area enclosed within the lateral ties.

(b) The ratio of longitudinal reinforcement to the core area shall be not less than 0.01 nor shall the ratio considered in the calculations be more than 0.03 of the core area of the column, nor more than .02 of the gross area. The longitudinal reinforcement shall consist of not less than four bars of minimum diameter of ⅝ inches placed with clear distance from the face of the column not less than 1½ inches, nor more than 3 inches. Splices in longitudinal reinforcement shall occur only where the column is laterally supported and shall provide sufficient lap to transmit the stress by bond, but not less than 24-bar diameters for deformed bars, and 30 diameters for plain bars.

(c) Lateral ties shall be at least ¼ inch in diameter spaced not more than 8 inches apart nor more than the least dimension of the column. In columns of rectangular section, cross-ties shall be arranged to afford support to the vertical bars at intervals not greater than the shorter side of the section, but such interval need not be less than 12 inches in any case.

Bending in Columns

125. (a) Stresses due to the bending moments in interior and exterior columns shall be determined on the basis of loading conditions and end restraint, and the columns designed for the combined bending and axial load stresses.

(b) In flat-slab construction, the least dimension of the column shall be not less than one-fifteenth of the average center to center span, nor less than 16 inches except for roof columns which shall be not less than 12 inches in least dimension. For known eccentric loads or unequal spacing of columns, computations of moments shall be made accordingly. Wall columns in flat-slab construction shall be designed to resist a bending moment of $Wl/35$, where W is the total load, dead and live, and l equals length of span. Any counter moment due to the weight of the structure that projects beyond the column center line may be deducted from the moment computed as just described. Resistance to the bending moments shall be divided between the columns immediately above and below in direct proportion to the values of their ratios of I/h. In which $I =$ moment of inertia of a section of the core about the axis of the column and $h =$ unsupported length of column.

(c) Recognized methods shall be followed in calculating the stresses due to combined axial load and bending. The column section shall be not less than that required where axial load alone is considered. The limiting combined unit stresses shall be as follows:

(1) Columns with spiral reinforcement,

$f_c = (.25 + 12\,p')\,f'_c + 0.15\,f_c'$ but not more than $.5\,f'_c$.

(2) Columns with lateral ties $0.3\,f'_c$. The total amount of reinforcement considered in the computations shall be not more than 4 per cent of the core area or more than 3 per cent of the gross area of the column.

(3) Tension in longitudinal reinforcement due to bending on the column shall not exceed 16,000 lb. per sq. in.

(d) Columns subject to both axial load and bending stresses due to wind loads may be proportioned for unit stresses not more than 50 per cent larger than those allowed for direct axial load; but the section shall be not less than that required for axial load and bending.

Long Columns

126. (a) The permissible working load on the core in axially loaded spiral or tied columns which have a length greater than 12 times the least dimensions of the column ($12D$) shall be not greater than that determined by formula (39):

$$\frac{P'}{P} = 1.33 - \frac{h}{36D} \qquad (39)$$

In which $P' =$ total safe axial load on long column and $P =$ safe axial load on column of the same section whose length is not greater than 12 times the least dimension of the column.

FOOTINGS

General

127. The requirements for tension, compression, shear and bond in Sections 84 and 119, inclusive, shall govern the design of footings, except as hereinafter provided.

Soil Footings

128. The load per unit of area on soil footings shall be computed by dividing the total load on the footing by the area of the base, giving proper consideration to any eccentricity that may exist.

Footings on piles shall be treated in the same manner as footings on soil, except that the load shall be considered as concentrated at the pile centers.

Sloped or Stepped Footings

129. Footings in which the thickness has been determined by the requirements for shear as specified in Sections 112 and 113 may be sloped or stepped between the critical section and the edge of the footing, provided that the shear on no section outside the critical section exceeds the value specified, and provided further that the thickness of the footing above the reinforcement at the edge shall not be less than 9 in. for footings on soil nor less than 12 in. for footings on piles. Sloped or stepped footings shall be cast as a unit.

Critical Section for Bending

130. The critical section for bending in a concrete footing which supports a concrete column or pedestal, shall be considered to be at the face of the column or pedestal. Where steel or cast-iron column bases are used, the moment in the footing shall be computed at the middle and at the edge of the base; the load shall be considered as uniformly distributed over the column or pedestal base except where there is eccentric loading.

The bending moment at the critical section in a square footing supporting a concentric square column shall be computed from the load on the trapezoid bounded by one face of the column, the corresponding outside edge of the footing and the portions of the two diagonals. The load on the two corner triangles of this trapezoid shall be considered as applied at a distance from the face equal to six-tenths of the projection of the footing from the face of the column. The load on the rectangular portion of the trapezoid shall be considered as applied at its center of gravity. The bending moment is expressed by the formula

$$M = \frac{w}{2}(a + 1.2\,c)\,c^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (40)$$

where M = bending moment at critical section of footing;
a = width of face of column or pedestal;
c = projection of footing from face of column; and
w = upward reaction per unit of area of base of footing.

For a round or octagonal column, the distance a shall be taken as equal to the side of a square of an area equal to the area enclosed within the perimeter of the column.

Reinforcement

131. The reinforcement in each direction in the footing shall be determined as for a reinforced concrete beam; the effective depth shall be the distance from the top of the footing to the plane of the reinforcement. The sectional area of reinforcement shall be distributed uniformly across the footing unless the width is greater than the side of the column or pedestal plus twice the effective depth of the footing, in which case the width over which the reinforcement is spread may be increased to include one-half the remaining width of the footing. In order that no considerable area of the footing shall remain unreinforced, additional reinforcement shall be placed outside of the width specified, but such reinforcement shall not be considered

as effective in resisting the calculated bending moment. For the extra reinforcement a spacing double that within the effective belt may be used.

Concrete Stress

132. The extreme fiber stress in compression in the concrete shall be kept within the limits specified in Section 183. The extreme fiber stress in sloped or stepped footings shall be based on the exact shape of the section for a width not greater than that assumed effective for reinforcement.

Irregular Footings

133. A rectangular or irregularly shaped footing shall be computed by dividing it into rectangles or trapezoids tributary to the sides of the column, using the distance to the center of gravity of the area as the moment arm of the upward forces. Outstanding portions of combined footings shall be treated in the same manner. Other portions of combined footings shall be designed as beams or slabs.

Transfer of Stress at Base of Column

134. The compressive stress in longitudinal reinforcement at the base of a column shall be transferred to the pedestal or footing by either dowels or distributing bases. When dowels are used, there shall be at least one for each column bar, and the total sectional area of the dowels shall be not less than the sectional area of the longitudinal reinforcement in the column. The dowels shall extend into the column and into the pedestal or footing not less than 50 diameters of the dowel bars for plain bars, or 40 diameters for deformed bars.

When metal distributing bases are used, they shall have sufficient area and thickness to transmit safely the load from the longitudinal reinforcement in compression and bending. The permissible compressive unit stress on top of the pedestal or footing directly under the column base shall be not greater than $.35f'_c$, the minimum distance from the edge of the column base to the edge of the top of footing being 3 in., and the area of the top of pedestal being at least twice the area of the column base.

Pedestals Without Reinforcement

135. The allowable compressive unit stress on the gross area of a concentrically loaded pedestal or on the minimum area of a pedestal footing shall not exceed $0.25\ f'_c$, unless reinforcement is provided and the member designed as a reinforced concrete column.

The depth of a pedestal or pedestal footing shall be not greater than three times its least width and the projection on any side from the face of the supported member shall be not greater than one-half the depth. The depth of a pedestal whose sides are sloped or stepped shall not exceed three times the least width or diameter of the section midway between the top and bottom. A pedestal footing supported directly on piles shall have a mat of reinforcing bars having a cross-sectional area of not less than 0.20 sq. in. per foot in each direction, placed 3 in. above the top of the piles.

[5]DESIGN OF RETAINING WALLS

NOTE.—For figures, formulas and principles of design, see Appendix B, page 650.

Notation

136.

ϕ = the angle of repose of the filling.

θ = the angle between the back of the wall and a horizontal line passing through the heel of the wall and extending from the back into the fill.

δ = angle of surcharge, which is the angle between a horizontal line and the surface of the filling. (It is recommended that values of $\delta = 0$ or $\delta = \phi$ be used.)

λ = the angle between the resultant thrust P and a horizontal line.

h = vertical height of the wall in feet.

h^1 = height of surcharge in feet.

l = width of the base of the wall in feet.

e = distance from the center of the base to the intersection of the resultant thrust E and the base.

$a = \dfrac{l}{2} - e$ = distance from toe of wall to intersection of the resultant thrust E and the base.

P = the resultant earth pressure per foot of length of wall.

E = the resultant of the earth pressure and the weight of the wall.

F = vertical component of resultant E.

w = the weight of the filling per cubic foot.

w_1 = the weight of the masonry per cubic foot.

W = total weight of the wall per foot of length.

p_1 and p_2 = pressure per square foot on the foundation, due to F, at toe and heel, respectively.

Formulas

137. The following formulas for vertical walls or for walls leaning away from the filling are based on Rankine's Theory, as given in Howe's "Retaining Walls," and in Ketchum's "Walls, Bins and Grain Elevators"; and the formulas for walls leaning toward the filling are based on a modification of Rankine's Theory, as given in Ketchum's "Walls, Bins and Grain Elevators."

For vertical walls with horizontal surcharge the pressure P is given by the formula

$$P = \frac{p_1}{2} wh^2 \frac{p_2 - \sin\phi}{1 + \sin\phi} = \frac{1}{2} wh^2 \tan^2\left(45° - \frac{\phi}{2}\right) \quad \ldots\ldots\ldots\ldots (41)$$

where P is parallel to the top surface, is normal to the wall, and is applied at one-third the height of the wall above the base.

For the vertical walls with a positive surcharge ϕ the pressure P is given by the formula

$$P = \frac{1}{2} wh^2 \cos\delta \frac{\cos\delta - \sqrt{\cos^2\delta - \cos^2\phi}}{\cos\delta - \sqrt{\cos^2\delta - \cos^2\phi}} \quad \ldots\ldots\ldots\ldots (42)$$

where P is parallel to the top surface of the filling, makes an angle δ with a normal to the back of the wall, and is applied at one-third the height of the wall above the base. Where the surcharge δ is equal to the angle of repose ϕ formula (42) becomes

$$P = \frac{1}{2} wh^2 \cos\phi \quad \ldots\ldots\ldots\ldots (43)$$

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[5] Adopted, Vol. 18, 1917, pp. 875, 1564; Vol. 28, 1927, pp. 1055, 1447.

For a vertical wall with a loaded surcharge the resultant pressure on the back of the wall will be given by the formula

$$P = \frac{1}{2} wh\,(h + 2h^1)\,\frac{1 - \sin\phi}{1 + \sin\phi} \tag{44}$$

where h is the height of the wall and h^1 is the equivalent height of surcharge, which is equal to the surcharge per square foot divided by w, the weight per cubic foot of the filling.

The resultant pressure is horizontal and is applied at a distance from the base of the wall equal to

$$y = \frac{h^2 + 3hh^1}{3\,(h + 2h^1)} \tag{45}$$

PRESSURE ON FOUNDATIONS

.... The pressures on the foundations will be calculated by the following formulas:

Where a is equal to or greater than $\frac{l}{3}$

Pressure at the toe

$$p_1 = (4l - 6a)\,\frac{F}{l^2} \tag{46}$$

Pressure at the heel is

$$p_2 = (6a - 2l)\,\frac{F}{l^2} \tag{47}$$

Where a is less than $\frac{l}{3}$, the pressure at the toe is

$$p_1 = \frac{2F}{3a} \tag{48}$$

Loading

138. (a) In calculating the surcharge due to a track, the entire load shall be taken as distributed uniformly over a width of 14 feet for a single track or tracks spaced more than 14 feet centers, and the distance center to center of tracks where tracks are spaced less than 14 feet.

(b) In calculating the pressure on a retaining wall where the filling carries permanent tracks or structures, the full effect of the loaded surcharge shall be considered where the edge of the distributed load or the structure is vertically above the back edge of the heel of the wall. The effect of the loaded surcharge may be neglected where the edge of the distributed load or the structure is at a distance from the vertical line through the back edge of the heel of the wall equal to h, the height of the wall. For intermediate positions, the equivalent uniform surcharge load is to be taken as proportional. For example, for a track with the edge of the distributed load at a distance, $\frac{h}{2}$, from the vertical line through the back edge of the heel of the wall, the equivalent uniform surcharge load is one-half the normal distributed load distributed over the filling. (See Appendix B).

REINFORCED CONCRETE RETAINING WALLS

Loads and Unit Stresses

139. Reinforced concrete retaining walls shall be so designed that the permissible unit stresses are not exceeded. The heels of cantilever, counterforted and buttressed retaining walls shall be proportioned for maximum resultant vertical loads, but when the foundation reaction is neglected the permissible unit stresses shall not be more than 50 per cent greater than the normal permissible stresses.

Details of Design

140. The following principles shall be followed in the design of reinforced concrete retaining walls:

(a) The unsupported toe and heel of the base slabs shall be considered as cantilever beams fixed at the edge of the support.

(b) The vertical section of a cantilever wall shall be considered as a cantilever beam fixed at the top of the base.

(c) The vertical sections of counterforted and buttressed walls and parts of base slabs supported by the counterforts or buttresses shall be designed in accordance with the requirements for a continuous slab in Section 91.

(d) The exposed faces of walls without buttresses shall preferably be given a batter of not less than ¼ in. per ft.

(e) Counterforts shall be designed in accordance with the requirements for T-Beams. Stirrups shall be provided in the counterforts to take the reaction when the tension reinforcement of the face walls and heels of bases is designed to span between the counterforts. Stirrups shall be anchored as near the exposed face of the longitudinal wall and as close to the lower face of the base as the requirements for protective covering permit.

(f) Buttresses shall be designed in accordance with the requirements specified for rectangular beams.

(g) The shearing stress at the junction of the base with counterforts or buttresses shall not exceed the values specified in Sections 102 to 113.

(h) Horizontal metal reinforcement shall be of such form and so distributed as to develop the required bond. To prevent temperature and shrinkage cracks in exposed surface not less than 0.25 sq. in. of horizontal metal reinforcement per foot of height shall be provided.

(i) Grooved lock joints shall be placed not over 60 ft. apart to care for temperature changes.

(j) Counterforts and buttresses shall be located under all points of concentrated loading, and at intermediate points, as may be required by the design.

(k) The walls shall be cast as a unit between expansion joints, unless construction joints formed in accordance with the provisions of these specifications are provided.

(l) Drains or "weep holes" not less than 4 in. in diameter and not more than 10 ft. apart, shall be provided. At least one drain shall be provided for each pocket formed by counterforts.

[c]SPECIFICATIONS FOR REINFORCED CONCRETE CULVERT PIPE

(I) GENERAL

Scope

141. These specifications apply to reinforced concrete pipe intended to be used for the construction of culverts.

Classes

142. Pipe, under these specifications, shall be of two classes known respectively as *Standard Reinforced Concrete Culvert Pipe* and *Extra Strength Reinforced Concrete Culvert Pipe.*

Basis of Acceptance

143. The acceptability of pipe shall be determined by the results of the strength and absorption tests hereinafter specified, if and when required, and by inspection to determine whether the pipe comply with the specifications as to design, and freedom from defects.

(II) MATERIALS

Reinforced Concrete

144. The reinforced concrete shall consist of Portland cement, mineral aggregate and water in which steel has been embedded in such a manner that the steel and the concrete act together in resisting forces.

Cement

145. Portland cement shall meet the requirements of the current Standard Specifications and Tests for Portland Cement of the American Railway Engineering Association.

Steel

146. Reinforcement may consist of wire which meets the requirements of the current Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement of the American Society for Testing Materials, or of bars which meet the requirements of the current Specifications for Billet Steel Concrete Reinforcement Bars of the American Railway Engineering Association.

Fine Aggregate

147. (a) Fine aggregate shall consist of sand, stone screenings, or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust lumps, soft or flaky particles, shale, alkali, organic matter,

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[c]Adopted, Vol. 30, 1929, pp. 790, 1461.

loam or other deleterious substances. Fine aggregate shall be well graded and shall pass a ¼ inch screen.

Coarse Aggregate

(b) Coarse aggregate shall consist of crushed stone, gravel, slag, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles, free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic or other deleterious matter.

Mixture

148. The aggregates shall be so graded and proportioned and thoroughly mixed with such a proportion of cement and water as will produce a homogeneous concrete mixture of such quality that the concrete will meet the test and design requirements herein specified.

(III) DESIGN

Methods of Design

149. The pipe shall be designed in accordance with the following assumptions:

(a) That the design load is equivalent to a vertical load uniformly distributed over the internal horizontal projection of the pipe, that the pipe is likewise uniformly supported and that no allowance is made for side pressure.

(b) The uniform load for the Standard Reinforced Concrete Culvert Pipe shall be 2000 lb. and for the Extra Strength Reinforced Concrete Culvert Pipe 4000 lb. per square foot respectively.

(c) The working stress per square inch in compression for the concrete shall not exceed three-eighths of the strength of concrete upon which the design is based.

(d) The ratio (n) of the modulus of elasticity of steel to that of concrete shall be 12 for concrete having an ultimate compressive strength at 28 days of 2750 lb. per sq. in. and 9 for concrete having an ultimate compressive strength of 4000 lb. per sq. in. or greater. Intermediate values of n shall be proportional to the strength of concrete assumed in the design.

(e) The working stress for cold-drawn steel wire shall not exceed 27,500 lb. per sq. in. For billet steel, intermediate and hard grades, the working stress shall not exceed 20,000 lb. per sq. in.; and for billet steel, structural grade, the working stress shall not exceed 18,000 lb. per sq. in.

(f) The distance from the center of the reinforcement to the nearest or tension surface of the concrete shall not be less than ¾ inch for pipe 12 inches or less in diameter, or less than one inch for pipe more than 12 inches in diameter.

(g) The distance from the center of the tension reinforcement to the compression surface of the concrete and the area of the reinforcement shall not be less than that required by the formula—

$$\frac{wd}{16} \times \frac{d+t}{12} = jAtf_s \qquad (49)$$

in which w = uniform vertical load in pounds per square foot top and bottom of pipe.

d = internal diameter of pipe in inches.

t = distance from the center of the tension reinforcement to the compression surface of the concrete in inches.

A = sectional area of tension reinforcement in square inches per linear foot of the pipe.

f_s = tensile stress in the reinforcement in pounds per square inch.

j = ratio of the lever arm of the reinforcement to t as determined by the usual formulas.

Minimum Designs

150. The shell thickness and the amount of circumferential reinforcement shall not be less than that given in the design tables for the classes and sizes of pipe and the strength of concrete therein specified.

Alternative Designs

151. Manufacturers may submit to the consumer or purchaser, for approval, designs based on strengths of concrete other than those given in the design tables. Such alternate design shall comply with the design requirements given in Section III of these specifications. In no alternative design, however, shall the shell thickness be less than those given in Table II, nor shall the strength of concrete be less than that given in Table I.

Standard Sizes

152. Pipe of the internal diameters listed in the design tables shall be considered standard sizes for culvert construction. In elliptical pipe, the inside diameter at the minor axis shall be equal to the diameter of the corresponding size of circular pipe.

Joints

153. The ends of the pipe shall be of such design that the pipe when laid shall make a continuous conduit with a smooth and uniform interior surface.

Placing Reinforcement

154. When a single line of circular reinforcement is used in circular pipe, it shall be placed at the center of the pipe shell. When two lines of reinforcement are used in circular pipe, one shall be placed near the inner and one near the outer surface of the pipe. The single line of elliptical reinforcement used in circular pipe, or the single line of circular reinforcement in elliptical pipe shall be placed near the inner surface at the "top" and "bottom" of the pipe and near the outer surface at the sides (see paragraph 160 (d)).

Longitudinals

155. Each line of circumferential reinforcement shall be assembled into a cage and have sufficient longitudinal bars or members, extending through

the barrel of the pipe, to afford rigidity and maintain the reinforcement in exact shape and correct position within the form.

Laps and Welds

156. The reinforcement shall be lapped not less than 30 diameters, or if welded, the joints shall develop the full strength of the reinforcement. The spacing center to center of adjacent rings of circumferential reinforcement in a cage shall not exceed 4 inches up to and including pipe 48 inches in diameter, nor exceed the shell thickness for larger pipe and shall in no case exceed 6 inches.

Bell Reinforcement

157. The bell shall have a circumferential reinforcement equal in unit area to that of a single line within the barrel of the pipe.

(IV) WORKMANSHIP AND FINISH

Finish

158. Pipe shall be substantially free from fractures, large or deep cracks and surface roughness. The planes of the ends of the pipe shall be perpendicular to their longitudinal axes.

Variations in Dimensions

159. (a) Variations of the internal diameter shall not exceed 1½ per cent nor shall the shell thickness be less than that intended in the design by more than 5 per cent at any point.

(b) Variation in the position of the reinforcement cages shall not exceed ¼ inch from the position provided in the design, nor shall the cover on the reinforcement be less than ¾ inch at any point.

(V) MARKING

Markings

160. The following shall be clearly stenciled on the pipe:

(a) The pipe class {by an "S" for Standard Pipe and an "X" for Extra Strength Pipe.

(b) The date of manufacture.

(c) The name or trade-mark of manufacturer.

(d) Elliptical pipe with circular reinforcing and circular pipe with elliptical reinforcing shall have the words "Top" "Bottom" clearly stenciled on the inside of the pipe at the correct place to indicate the proper position when laid.

(VI) PHYSICAL TESTS

Strength Tests

161. Pipe may be tested for strength by either the three-edge or sand bearing method:

Three-Edge Bearing Tests

162. When the three-edge bearing is used, the lower bearing for the pipe shall consist of two wooden strips with vertical sides having their interior top corners rounded to a radius of approximately ½ inch. The strips shall be straight and shall be securely fastened to a rigid block with the interior vertical sides spaced a distance apart not less than ½ inch nor more than 1 inch for each foot of diameter pipe. The upper bearing shall be a rigid wooden block, straight and true from end to end. The upper and lower bearings shall extend the full length of pipe exclusive of bell. The pipe shall be placed symmetrically between the two bearings as illustrated in Fig. 3 and 4. In testing pipe which is "out of line" the lines of the bearings chosen shall be from those which appear to give the most favorable conditions for fair test.

Sand Bearing Test

163. When sand bearings are used (see Fig. 2 and 5), the ends of each specimen of the pipe shall be accurately marked prior to the test in quarters of the circumference. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.

The sand used shall be clean and moist, and shall be such as will pass a 4760-micron sieve (U.S. Standard No. 4). The sand in the lower bearing shall be loose when the pipe is placed.

The top bearing frame shall not be allowed to come in contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be stuck level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, or in such manner as to produce uniform deflection throughout the full length of the pipe. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.

The frames of the top and bottom bearings shall be made of timber so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

Application of Load (Testing Machine)

164. It is desirable that a machine shall be used which gives a uniform deflection throughout the full length of the pipe. Any mechanical

or hand power device may be used in which the head that applies the load moves at a speed of not more than 0.05 inch per minute while making the test. The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part. The load shall be applied continuously until the ultimate strength of the pipe is reached.

Strength Requirements

165. The ultimate load, as determined by one of the methods described in paragraphs 166 and 167, shall not be less than the ultimate load specified in Table V for the size and class of pipe that is being tested. When the test load reaches the cracking load specified in Table V for the size and class of pipe that is being tested, there shall be in the barrel of the pipe no crack having a surface width of 1/100 inch* or more, for a length of one foot or more. The ultimate load is reached when the pipe will sustain no greater load.

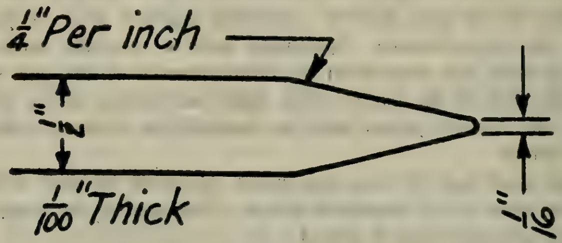

Fig. 1

Elliptical Pipe

166. Elliptical pipe shall meet the test requirements for circular pipe having the same horizontal internal diameter.

Preliminary Tests and Tests for Extended Deliveries

167. Preliminary to placing an order, a consumer of pipe whose needs require shipments at intervals over extended periods of time shall be entitled to test not more than ten pieces of pipe covering the size in which he is interested. The test specimens shall be selected in approximately equal numbers from the larger and smaller sizes of pipe. The acceptability of the larger sizes of pipe shall not be based on the results of tests in smaller sizes. After these preliminary tests, a consumer shall be entitled to additional tests in such numbers and at such times as he may deem necessary, provided that the total number of pipe tested shall not exceed two per cent of the total deliveries.

Tests for Occasional Orders

168. A purchaser who places occasional orders shall be entitled to test a number of pipe equal to two per cent of an order but not to exceed five

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*It is recommended that the width of the crack be measured by means of a gage made from a leaf 1/100 inch thick from a set of standard machinists' gages, ground to a point 1/16 inch wide, with corners rounded, and with a taper of 1/4 inch per inch, as illustrated by Fig. 1. The crack shall be considered to be 1/100 inch wide when the point of the gage will just enter it at close intervals.

pieces of any one size; otherwise the number of pipe desired for testing shall be included in the order.

Selecting Test Specimens

169. All pipe for testing purposes shall be selected at random by the consumer or purchaser from the stock of the manufacturer and shall be pipe which would not otherwise be rejected under these specifications. The pipe shall be free from visible moisture when tested.

They shall not have been exposed to a temperature below 40 deg. Fahr. for the 24 hours immediately preceding the test.

Cylinder Tests and Reinforcement Examinations

170. By agreement between the consumer and the manufacturer the continued acceptability of the pipe, after the preliminary pipe tests have been made, may be determined by tests of the quality of the concrete as placed in the pipe and examination of the quality, amount and the accuracy of placement of the reinforcement. The quality of the concrete shall be determined on 6 by 12 in. test cylinders taken from the concrete used in making the pipe and manufactured and cured under identical conditions with the pipe. When tested in accordance with the current standard methods prescribed by the American Society for Testing Materials, these cylinders shall have a strength not less than that assumed in the design of the pipe.

Retests

171. Pipe shall be acceptable under the strength tests when all test specimens meet the test requirements. Should less than three of the ten preliminary test specimens or any one of the additional test specimens provided for in paragraph 167, or any one specimen provided for in paragraph 168 fail to meet the test requirements, then the manufacturer will be allowed a retest on two like specimens for each specimen that failed, and the pipe shall be acceptable only when all of these retest specimens meet the test requirements. No further retests shall be permitted.

Test Specimens

172. Absorption tests shall be made by the following method:

(a) The number of absorption specimens shall be equal to the number of pipe provided for testing. The specimens shall be obtained from pipe that are acceptable as to strength and shall be taken from pipe used in making the strength test when that test is made. The specimens shall be marked with the number or identifying mark of the pipe from which they were taken. Each specimen shall have an area of 16 to 24 square inches and a thickness equal to the full depth of the pipe shell and shall be free from visible cracks.

Drying Specimens

(b) Specimens shall be dried at a temperature of approximately 110 deg. C. (230 deg. Fahr.) until no loss of weight is shown by successive weighings at intervals of not less than four hours.

Immersion and Reweighing

(c) The dried specimens shall be placed in a suitable receptacle, covered with distilled water or rain water, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of from 15 deg. to 20 deg. C. (59 deg. to 68 deg. Fahr.). When cool, the specimens shall be removed from the water, allowed to drain for not more than one minute, the superficial water removed by a towel or blotting paper, and the specimens immediately weighed.

Weighing Devices

(d) The balance used shall be sensitive to 0.5 g., when loaded with 1 kg. and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same degree of accuracy must be obtained.

Calculation and Reporting of Results

(e) The increase in weight of the boiled specimen over its dry weight shall be considered the absorption of the specimen and shall be calculated as a percentage of the dry weight. The results shall be reported separately for each specimen.

Test Requirements and Acceptability Under Absorption Tests

173. The absorption shall not exceed 8 per cent for test specimens taken from pipe designed to be made of concrete having a compressive strength of 3000 or more pounds per square inch, or 9 per cent for test specimens taken from pipe designed to be made of concrete having a compressive strength of less than 3000 lb. per square inch. Pipe shall be considered to meet these specifications for absorption when not less than 80 per cent of the number of specimens tested, including any retested, meet the test requirements. When the initial absorption specimen from a pipe fails to meet these specifications, the absorption test shall be made on another specimen from the same pipe and the results of the retest shall be substituted for the original test results.

Minimum Age for Shipment

174. Pipe will be considered ready for shipment when they meet the test requirements, or when tests of 6 by 12 inch cylinders (Section 170) show that the concrete has attained the strength assumed in the design of the pipe.

Test Equipment

175. Every manufacturer furnishing pipe under these specifications shall furnish all facilities necessary to carry out the tests herein provided.

(VII) INSPECTION

Inspection

176. All materials, processes of manufacture and finished pipe shall be subject to inspection and approval by an inspector employed by the consumer or purchaser. The manufacturer when so directed by the inspector

shall have holes cut in such sections of the finished pipe (not exceeding one hole in every 50 sections delivered) as desired so that a proper inspection may be made of the quantity and placement of the reinforcement. If the pipes are tested for strength or absorption, inspection of the reinforcement shall be made on the pipe used for those tests, and in no case shall the total number of pipe cut open for inspection of reinforcement exceed the number to which the purchaser is entitled under the provisions of Sections 167 and 168.

Causes for Rejection of Pipe

177. Pipe shall be subject to rejection on account of failure to meet any of the specification requirements or on account of any of the following:

(a) Fractures or cracks passing through the shell, except that an end crack that does not exceed the depth of the joint, or a fracture that at its deepest point does not exceed the depth of the joint nor extend more than ten per cent around the circumference, shall not be considered cause for rejection unless these defects exist in more than five per cent of the pipe inspected.

(b) Defects which indicate imperfect mixing and molding.

(c) Exposure of the reinforcement when such exposure would indicate that the reinforcement is misplaced.

TABLE I—DESIGNS OF STANDARD REINFORCED CONCRETE CULVERT PIPE

For Uniform Load of 2000 Lb. Per Square Foot. Ultimate Compressive Strength of Concrete, 2750 Lb. per Square Inch

($f_c = 1030$ lb.)

Internal Diameter of Pipe in Inches "d"	Minimum Thickness of Shell in Inches	Min. Dist. Center Reinforcement to Compressive Surface in Inches "t"		Minimum Area of Circular Reinforcement Square Inches per Lineal Foot of Pipe "A"			
				Cold Drawn Steel Wire $f_s = 27{,}500$ lbs. sq. in.		Billet Steel Hard and Intermediate Grades $f_s = 20{,}000$ lbs. sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
12	2	1		1 Line .07		1 Line .09	
15	2¼	1⅛	1¼	1 " .09	1 " .08	1 " .13	1 " .12
18	2½	1¼	1½	1 " .12	1 " .10	1 " .17	1 " .14
24	3	1½	2	1 " .17	1 " .13	1 " .25	1 " .19
30	3½	1¾	2½	1 " .23	1 " .17	1 " .32	1 " .23
30	3½	2½	2½	2 "ea. .17	1 " .17	2 "ea. .23	1 " .23
36	4	3	3	2 " " .20	1 " .20	2 " " .28	1 " .28
42	4½	3½	3½	2 " " .23	1 " .23	2 " " .32	1 " .32
48	5	4	4	2 " " .26	1 " .26	2 " " .37	1 " .37
54	5½	4½	4½	2 " " .30	1 " .30	2 " " .42	1 " .42
60	6	5	5	2 " " .33	1 " .33	2 " " .46	1 " .46
72	7	6	6	2 " " .40	1 " .40	2 " " .56	1 " .56
84	8	7	7	2 " " .46	1 " .46	2 " " .65	1 " .65

TABLE II—DESIGNS OF STANDARD REINFORCED CONCRETE CULVERT PIPE

For Uniform Load of 2000 Lb. Per Square Foot. Ultimate Compressive Strength of Concrete 4000 Lb. per Square Inch

($f_c = 1500$ lb.)

Internal Diameter of Pipe in Inches "d"	Minimum Thickness of Shell in Inches	Min. Dist. Center Reinforcement to Compressive Surface in Inches "t"		Minimum Area of Circular Reinforcement Square Inches per Lineal Foot of Pipe "A"			
				Cold Drawn Steel Wire $f_s = 27{,}500$ lbs. sq. in.		Billet Steel Hard and Intermediate Grades $f_s = 20{,}000$ lbs. sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
12	1¾	⅞		1 Line .08		1 Line .11	
15	2	1		1 " .11		1 " .15	
18	2¼	1⅛	1¼	1 " .14	1 " .12	1 " .19	1 " .17
24	2⅝	1¼	1⅝	1 " .21	1 " .17	1 " .30	1 " .23
30	3	1½	2	1 " .29	1 " .21	1 " .38	1 " .29
30	3	2	2	2 " ea. 21	1 " .21	2 "ea. .29	1 " .29
36	3⅜	2⅜	2⅜	2 " " .26	1 " .26	2 " " .36	1 " .36
42	3¾	2¾	2¾	2 " " .30	1 " .30	2 " " .41	1 " .41
48	4¼	3¼	3¼	2 " " .34	1 " .34	2 " " .46	1 " .46
54	4⅝	3⅝	3⅝	2 " " .38	1 " .38	2 " " .52	1 " .52
60	5	4	4	2 " " .42	1 " .42	2 " " .59	1 " .59
72	5¾	4¾	4¾	2 " " .51	1 " .51	2 " " .71	1 " .71
84	6⅝	5⅝	5⅝	2 " " .60	1 " .60	2 " " .82	1 " .82

TABLE III—DESIGNS OF EXTRA STRENGTH REINFORCED CONCRETE CULVERT PIPE

For Uniform Load of 4000 Lb. Per Square Foot. Ultimate Compressive Strength of Concrete, 2750 Lb. per Square Inch

($f_c = 1030$ lb.)

Internal Diameter of Pipe in Inches "d"	Minimum Thickness of Shell in Inches	Min. Dist. Center Reinforcement to Compressive Surface in Inches "t"		Minimum Area of Circular Reinforcement Square Inches per Lineal Foot of Pipe "A"			
				Cold Drawn Steel Wire $f_s = 27{,}500$ lbs. sq. in.		Billet Steel Hard and Intermediate Grades $f_s = 20{,}000$ lbs. sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforce ment in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
12	2½	1¼	1½	1 Line .11	1 Line .09	1 Line .15	1 Line .13
15	2¾	1⅜	1¾	1 " .15	1 " .12	1 " .21	1 " .17
18	3⅛	1⅝	2⅛	1 " .18	1 " .14	1 " .26	1 " .20
24	3⅞	2	2⅞	1 " .26	1 " .19	1 " .37	1 " .27
30	4⅝	2¼	3⅝	1 " .36	1 " .23	1 " .51	1 " .33
30	4⅝	3⅝	3⅝	2 " ea..23	1 " .23	2 "ea. .33	1 " .33
36	5⅜	4⅜	4⅜	2 " " .28	1 " .28	2 " " .40	1 " .40
42	6	5	5	2 " " .33	1 " .33	2 " " .47	1 " .47
48	6¾	5¾	5¾	2 " " .38	1 " .38	2 " " .53	1 " .53
54	7½	6½	6½	2 " " .42	1 " .42	2 " " .60	1 " .60
60	8¼	7¼	7¼	2 " " .47	1 " .47	2 " " .66	1 " .66
72	9⅝	8⅝	8⅝	2 " " .57	1 " .57	2 " " .80	1 " .80
84	11	10	10	2 " " .67	1 " .67	2 " " .94	1 " .94

TABLE IV—DESIGNS OF EXTRA STRENGTH REINFORCED CONCRETE CULVERT PIPE

For Uniform Load of 4000 Lb. Per Square Foot. Ultimate Compressive Strength of Concrete, 4750 Lb. per Square Inch

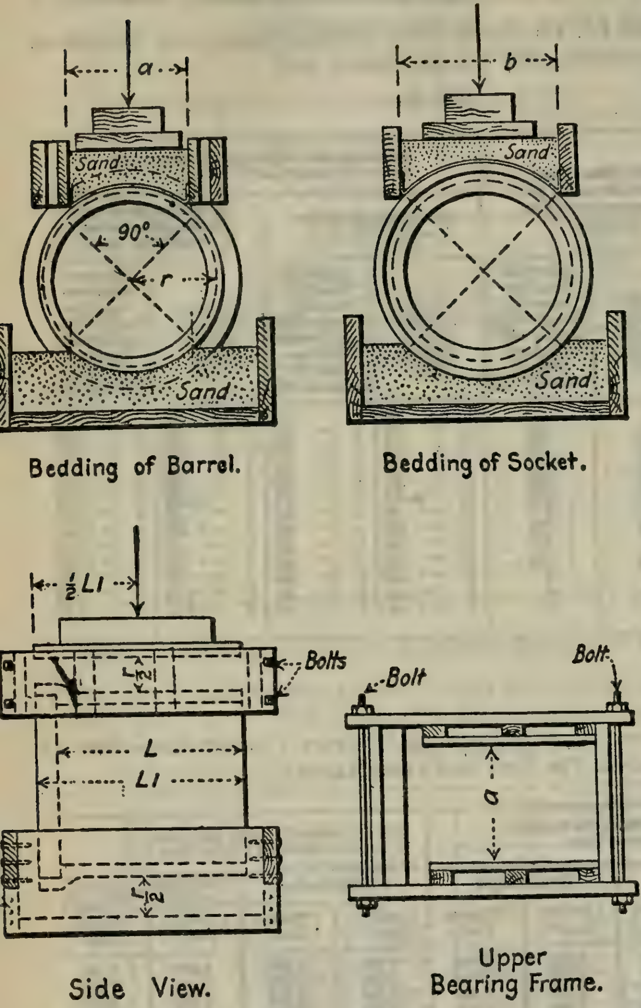
($f_c = 1780$ lb.)

Internal Diameter of Pipe in Inches "d"	Minimum Thickness of Shell in Inches	Min. Dist. Center Reinforcement to Compressive Surface in Inches "t"		Minimum Area of Circular Reinforcement Square Inches per Lineal Foot of Pipe "A"			
				Cold Drawn Steel Wire $f_s = 27{,}500$ lbs. sq. in.		Billet Steel Hard and Intermediate Grades $f_s = 20{,}000$ lbs. sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
12	2	1		1 Line .14		1 Line .19	
15	2¼	1⅛	1¼	1 " .19	1 " .17	1 " .26	1 " .24
18	2½	1¼	1½	1 " .24	1 " .21	1 " .34	1 " .29
24	3	1½	2	1 " .35	1 " .27	1 " .50	1 " .39
30	3½	1¾	2½	1 " .47	1 " .34	1 " .66	1 " .48
30	3½	2½	2½	2 " ea..34	1 " .34	2 " ea..48	1 " .48
36	4	3	3	2 " " .41	1 " .41	2 " " .57	1 " .57
42	4½	3½	3½	2 " " .48	1 " .48	2 " " .67	1 " .67
48	5	4	4	2 " " .55	1 " .55	2 " " .76	1 " .76
54	5½	4½	4½	2 " " .62	1 " .62	2 " " .86	1 " .86
60	6	5	5	2 " " .68	1 " .68	2 " " .95	1 " .95
72	7	6	6	2 " " .82	1 " .82	2 " " 1.14	1 " 1.14
84	8	7	7	2 " " .96	1 " .96	2 " " 1.33	1 " 1.33

TABLE V—MINIMUM STRENGTH OF REINFORCED CONCRETE CULVERT PIPE—PIPE IN POUNDS PER FOOT OF LAYING LENGTH

Size of Pipe	Standard Reinforced Concrete Culvert Pipe				Extra Strength Reinforced Concrete Culvert Pipe			
	3 Edge Bearing		Sand Bearing		3 Edge Bearing		Sand Bearing	
	Cracking Load*	Ultimate Load	Cracking Load*	Ultimate Load	Cracking Load*	Ultimate Load	Cracking Load*	Ultimate Load
12"	1,600	2,000	2,400	3,000	3,200	4,000	4,800	6,000
15"	1,800	2,500	2,700	3,750	3,600	5,000	5,400	7,500
18"	2,000	3,000	3,000	4,500	4,000	6,000	6,000	9,000
24"	2,200	4,000	3,300	6,000	4,400	8,000	6,600	12,000
30"	2,500	5,000	3,750	7,500	5,000	10,000	7,500	15,000
36"	3,000	6,000	4,500	9,000	6,000	12,000	9,000	18,000
42"	3,500	7,000	5,250	10,500	7,000	14,000	10,500	21,500
48"	4,000	8,000	6,000	12,000	8,000	16,000	12,000	24,000
54"	4,500	9,000	6,750	13,500	9,000	18,000	13,500	27,000
60"	5,000	10,000	7,500	15,000	10,000	20,000	15,000	30,000
72"	6,000	12,000	9,000	18,000	12,000	24,000	18,000	36,000
84"	7,000	14,000	10,500	21,000	14,000	28,000	21,000	42,000

*At the cracking load there shall be, in the barrel of the pipe, no crack having a surface width of .01 inch or more for a length of one foot or more.



Bedding of Barrel.

Bedding of Socket.

Side View.

Upper Bearing Frame.

Fig. 2
Sand Bearings

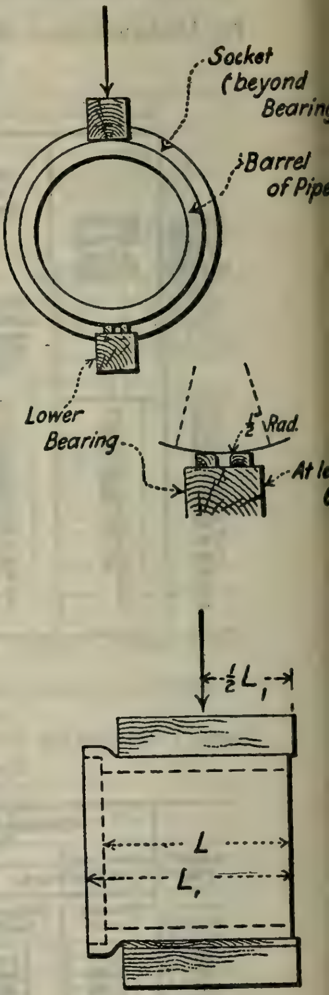
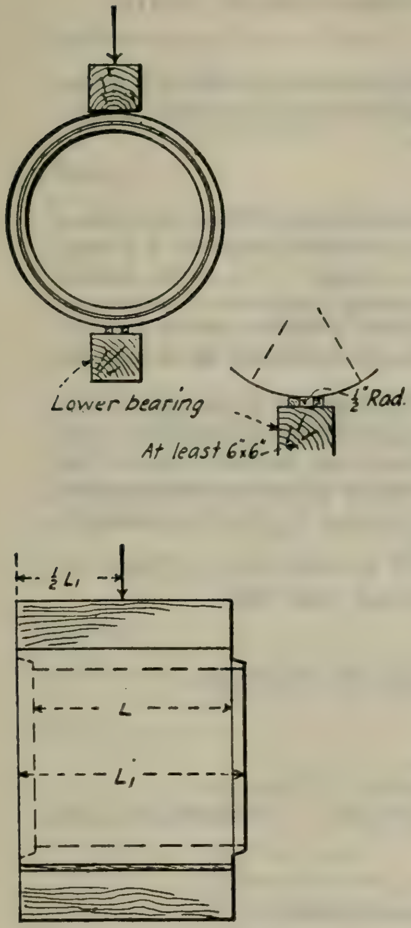
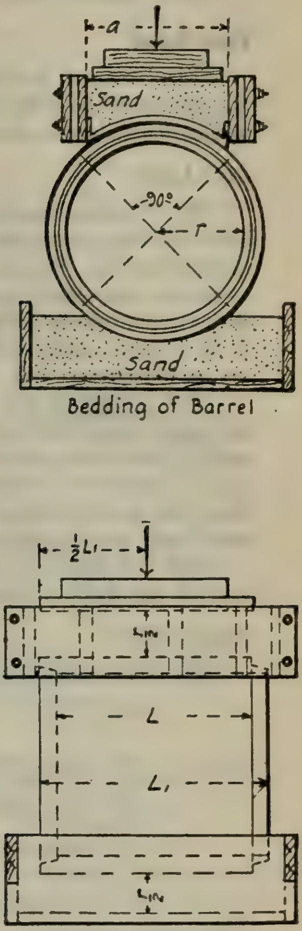


Fig. 3
Three Edge Bearings



Side View

Fig. 4
Three Edge Bearings



Side View

Fig. 5
Sand Bearings

[7]DISTRIBUTION OF LOADS TO GOVERN THE DESIGN OF RAILWAY STRUCTURES

(I) STRUCTURES UNDER EMBANKMENT LOADS

Dead Load

178. The dead load should be assumed as the weight of the track, ballast, fill and culvert masonry embraced within the vertical prism above the portion of the structure under investigation.

Live Load

179. The live load on structures buried to a depth of three feet or more below the base of rail shall be assumed as distributed uniformly in a longitudinal direction. Except as modified in paragraph 3, it is further assumed to spread transversely so as to give a uniform distribution of pressure on all horizontal planes lying between two planes inclined at outward slopes of ½ to 1, these planes being fixed by lines drawn through the ends of the ties at the base of rail.

The spread of the live load shall be assumed at not less than 13 feet unless slabs under relatively limited depths of fill are divided by longitudinal joints into units of such width that some possible location of the track or tracks will result in a concentration of the live load on the slab or slabs, that would necessarily exceed that indicated by the above assumption. Such cases must be analyzed individually.

The live load for a depth of fill of less than three feet below the base of rail shall be assumed as concentrated wheel loads.

Impact Load

180. The impact load shall be derived from the formula:

$$I = K \left[\frac{L + D}{L}\right] L \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (50)$$

where $I =$ the impact load
$D =$ the dead load as derived according to Paragraph (1)
$L =$ the live load as derived according to Paragraphs (2), (3) and (4)
$K =$ a co-efficient*.

SUMMARY OF WORKING STRESSES

General

181. The following working stresses shall be used:

where $f'_c =$ ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12 in. or 8 by 16 in. cylinders made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field and the Tentative Method of Making Compression Tests of Concrete.

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*No specific value for K is recommended but it is suggested that a value of 1.0 represents conservative practice.

[7]Adopted, Vol. 26, 1925, pp. 478, 485, 1326.

DIRECT STRESS IN CONCRETE

Direct Compression

182. Piers and pedestals (see Section 135) .... $0.25f'_c$

Compression in Extreme Fiber

183. Extreme fiber stress in flexure .... $0.35f'_c$
Extreme fiber stress in flexure adjacent to supports of continuous beams .... $0.40f'_c$

Tension

184. In reinforced concrete members .... None
In plain concrete .... $0.025f'_c$

SHEARING STRESS IN CONCRETE

Longitudinal Bars Without Special Anchorage

185. Beams without web reinforcement .... $0.02f'_c$
Beams with stirrups or bent-up bars or combination of the two .... $0.06f'_c$

Longitudinal Bars Having Special Anchorage

186. Beams without web reinforcement .... $0.03f'_c$
Beams with stirrups or bent-up bars or a combination of the two .... $.075f'_c$

Footings

187. (a) Longitudinal bars without special anchorage .... $0.03f'_c$
(b) Longitudinal bars having special anchorage .... $0.03f'_c$

STRESSES IN REINFORCEMENT

Tension in Steel

188. (a) Billet-Steel bars:
(1) Structural steel grade .... 16,000 lb. per sq. in.
(2) Intermediate grade .... 18,000 lb. per sq. in.
(3) Hard grade .... 18,000 lb. per sq. in.
(b) Structural steel .... 16,000 lb. per sq. in.
(c) Cold drawn steel wire .... 18,000 lb. per sq. in.

Compression in Steel

189. (a) Bars .... Same as Section 188a
(b) Structural steel core of composite column. 16,000 lb. per sq. in. Reduced for slenderness ratio
(c) Structural steel column .... 16,000 lb. per sq. in.

Compression in Cast-Iron

190. Composite cast-iron column .... 10,000 lb. per sq. in.

Bond Between Concrete and Reinforcement

191. (a) Beams and slabs, plain bars .... $0.04f'_c$
(b) Beams and slabs, deformed bars .... $0.05f'_c$
(c) Footings, plain bars, one-way .... $0.04f'_c$
(d) Footings, deformed bars, one way .... $0.05f'_c$
(e) Footings, bars two ways .... (c) or (d) reduced by 25 per cent.

Culvert Pipe

192. Compression in concrete .... $0.375f'_c$
Tension cold drawn steel wire .... 27,500 lb.
Billet-steel, intermediate and hard grades .... 20,000 lb.
Billet-steel structural grade .... 18,000 lb.

[8]SPECIFICATIONS FOR PORTLAND CEMENT

Definition

1. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

(I) CHEMICAL PROPERTIES

Chemical Limits

2. The following limits shall not be exceeded:
Loss on ignition, per cent 4.00
Insoluble residue, per cent 0.85
Sulfuric anhydride (SO_3), per cent 2.00
Magnesia (MgO), per cent 5.00

(II) PHYSICAL PROPERTIES

Fineness

3. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

4. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Time of Setting

5. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

Tensile Strength

6. The average tensile strength in pounds per square inch of not less than three standard mortar briquets (see Section 47), composed of one part of cement and three parts of standard sand, by weight, shall be equal to or higher than the following:

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[8] Adopted, Vol. 28, 1927, pp. 1094, 1453.

Age at Test, Days	*Storage of Briquets*	*Tensile Strength, Lb. Per. Sq. In.*
7	1 day in moist air, 6 days in water........	225
28	1 day in moist air, 27 days in water........	325

7. The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

(III) PACKING, MARKING AND STORAGE

Packages and Marking

8. The cement shall be delivered in packages as specified with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. When shipped in bulk, this information shall be contained in the shipping advices accompanying the shipment. A bag shall contain 94 lb. net. A barrel shall contain 376 lb. net. All packages shall be in good condition at the time of inspection.

Storage

9. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

(IV) INSPECTION

Inspection

10. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 12 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 33 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test need not be made if waived by the purchaser.

(V) REJECTION

Rejection

11. The cement may be rejected if it fails to meet any of the requirements of these specifications.

12. Cement remaining in storage prior to shipment for a period greater than 6 months after test shall be retested and shall be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100°C. for one hour it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter. The provisional acceptance of the cement at the mill shall not deprive the purchaser of the right of rejection on a retest of soundness and time of setting at the time of delivery of cement to the purchaser.

15. Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

Tests

(VI) SAMPLING

Number of Samples

16. Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 4 lb.

17. (a) Individual Sample.—If sampled in cars, one test sample shall be taken from each 50 bbl. or fraction thereof. If sampled in bins one sample shall represent each 200 bbl. unless otherwise specified by the purchaser.

(b) Composite Sample.—If sampled in cars, one sample shall be taken from one sack in each 40 sacks (or 1 bbl. in each 10 bbl.) and combined to form one test sample. If sampled in bins or warehouses one test sample shall represent not more than 200 bbl. unless otherwise specified by the purchaser.

Method of Sampling

18. Cement may be sampled at the mill by any of the following methods that may be practicable, as specified.

(a) From the Conveyor Delivering to the Bin.—At least 4 lb. of cement shall be taken from approximately each 100 bbl. passing over the conveyor. This may be secured by taking the entire test sample at a single operation, known as the "Grab Method," or by combining several portions taken at regular intervals, known as the "Composite Method."

(b) From Filled Bins by Means of Proper Sampling Tubes.—Tubes inserted vertically may be used for sampling cement to a maximum depth of 10 ft. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(c) From Filled Bins at Points of Discharge.—Sufficient cement shall be drawn from the discharge openings to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

19. The sampling shall be done by or under the direction of a responsible representative of the purchaser.

Treatment of Sample

20. Samples preferably shall be shipped and stored in moisture-proof, air-tight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample, break up lumps and remove foreign materials.

(VII) CHEMICAL ANALYSIS

LOSS ON IGNITION

Method

21. One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25-cc. capacity, as follows, using either Method (a) or (b) as specified:

METHOD (a): The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

METHOD (b): The crucible shall be placed in a muffle at any temperature between 900 and 1000°C. for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

Permissible Variation

22. A permissible variation of 0.25 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 4 per cent.

INSOLUBLE RESIDUE

Method

23. To a 1-g. sample of cement shall be added 25 cc. of water and 5 cc. of concentrated hydrochloric acid (sp. gr. 1.19). Material shall be ground with the flattened end of a glass rod until it is evident that the decomposition of the cement is complete. The solution shall then be diluted to 50 cc. and digested on a steam bath for 15 minutes. The residue shall be filtered, washed with cold water and the filter paper and contents digested in about 30 cc. of a 5-per-cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with hot water, then with a few drops of hot hydrochloric acid (1:9) and finally with hot water, then ignited at a red heat and weighed as the insoluble residue.

Permissible Variation

24. A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 0.85 per cent.

SULFURIC ANHYDRIDE

Method

25. To a 1-g. sample of cement shall be added 25 cc. of water and 5 cc. of concentrated hydrochloric acid (sp. gr. 1.19). Material shall be ground with the flattened end of a glass rod until it is evident that

decomposition of the cement is complete. The solution shall be diluted to 50 cc. and digested on a steam bath for 15 minutes, filtered, and the residue washed thoroughly with hot water. The solution shall be diluted to 250 cc., heated to boiling, and 10 cc. of a hot 10-per-cent solution of barium chloride shall be added slowly drop by drop, from a pipette and the boiling continued until the precipitate is well formed. The solution shall then be digested on the steam bath at least three hours, preferably over night. The precipitate shall be filtered, washed and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulfate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulfuric anhydride. The acid filtrate obtained in the determination of the insoluble residue may be used for the estimation of sulfuric anhydride instead of using a separate sample.

Permissible Variation

26. A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 2.00 per cent.

MAGNESIA

Method

27. To 0.5 g. of the cement in an evaporating dish shall be added 10 cc. of water to prevent lumping and then 10 cc. of concentrated hydrochloric acid (sp. gr. 1.19). The material shall be ground with the flattened end of a glass rod until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration, the residue may be heated to 150°C. or even 200°C. for one-half to one hour. The residue shall be treated with 10 cc. of hydrochloric acid diluted with an equal amount of water. The dish shall be covered, and the solution digested for 10 minutes on a steam bath or water bath. The solution shall be diluted to 75 cc., filtered into a beaker, and the separated silica washed thoroughly with hot water (Note 1). Five cubic centimeters of concentrated hydrochloric acid and two drops of methyl red indicator (0.2-per-cent alcoholic solution) shall be added to the filtrate (about 250 cc.) (Note 2).

NOTES

1. Since this procedure does not involve the determination of silica, a second evaporation is unnecessary.

2. Manganese, if present, is distributed between the precipitates of iron and alumina, calcium and magnesium. In the amounts usually present in Portland cement, it may be neglected. If it is desired to determine the small amount of manganese that may be present in the magnesium pyrophosphate, this may be done colorimetrically as described in the U. S. Geological Survey *Bulletin No. 700*, p. 153. If present in larger amounts, manganese should be precipitated with the iron and alumina, preferably by the persulfate method (U. S. Geological Survey *Bulletin No. 700*, p. 112). If this method is used more aluminum passes into solution than in the method above described.

Dilute ammonium hydroxide shall be added dropwise until the color of the solution changes to a distinct yellow. The solution shall be boiled for one or two minutes and filtered at once. The beaker and precipitate shall be washed slightly with a hot 2-per-cent solution of ammonium chloride (or ammonium nitrate). Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitating vessel and dissolved in 10 cc. of hot hydrochloric acid. The paper shall then be extracted with acid, the solution and washings being added to the solution of the precipitate. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide as before in a volume of about 100 cc. and the second precipitate shall be collected and washed with a hot 2-per-cent solution of ammonium chloride (or ammonium nitrate) on the filter used in the first instance, if this is still intact. To the combined filtrates from the hydroxides of iron and aluminum, reduced in volume if need be, 1 cc. of ammonium hydroxide shall be added, the solution brought to boiling, 25 cc. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well defined granular form. The precipitate after 1 hour shall be filtered and washed, and the filtrate set aside. The filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition, it shall be cautiously moistened with water, redissolved in hydrochloric acid and the solution diluted to 100 cc.; ammonia shall be added in slight excess, the liquid boiled, and filtered if a precipitate appears. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand till settled, filtered and washed. The combined filtrates from the calcium precipitates shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 cc. and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little iron and aluminum, and perhaps calcium). When cool, the solution shall be acidified with hydrochloric acid, 10 cc. of saturated solution of sodium-ammonium-hydrogen phosphate added, and ammonia drop by drop, with constant stirring. When the crystallin ammonium-magnesium orthophosphate has formed, 5 cc. excess ammonia shall be added. The solution shall be set aside for not less than 4 hours, preferably over night, in a cool place, filtered and washed with water containing 2.5 per cent NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 cc., 1 cc. of a saturated solution of sodium-ammonium-hydrogen phosphate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about 2 hours, filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

Permissible Variation

28. A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 5.00 per cent.

(VIII) DETERMINATION OF FINENESS

Apparatus

29. Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire, and mounted without distortion on frames about 2 in. below the top of the frame. The joint between the cloth and frame shall be smoothly filled with solder to prevent lodging of the cement. The sieve frames shall be circular, approximately 8 in. in diameter, and may be provided with a pan and cover.

30. A standard No. 200 sieve is one having nominally a 0.0029-in. opening, certified by the U. S. Bureau of Standards, and conforming to the specifications for this sieve in the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials.[1] The correction to the sieving value of the sieve shall be determined by sieving tests made in conformity with the standard specifications for these tests on a standardized cement which gives a residue of about 20 per cent on the No. 200 sieve.

Method

31. The test shall be made with 50 g. of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the up stroke. The sieve shall be turned every 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 g. passes through in one minute of continuous sieving (Note 1). The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample, applying the sieve correction (Note 2).

NOTES

1. The essential points in the sieving operation may be summarized as follows:

(1) Rotation of the sieve throughout the process.
(2) Guarding against loss of material. Sieve over white paper and always tap the sieve gently.

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[1] A.S.T.M. Standards Adopted in 1926.

(3) Use of a balance which will give results correct within 5 mg. and sufficiently sensitive so that the rest point will be deflected at least two divisions of the scale for an added load of 5 mg.
(4) Washers, shot and slugs should never be used on the sieve.
(5) Excessive humidity interferes with good sieving. It tends to decrease the percentage of cement passing the sieve, and in general, to produce irregular results.

2. A plus (+) sieve correction indicates the amount to be added to and a minus (—) sieve correction the amount to be subtracted from the per cent passing the sieve to obtain the true fineness. The per cent passing is the amount obtained by subtracting the per cent residue from 100. The corrections are used in the reverse order when applied to the residues direct.

32. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in Section 31.

(IX) MIXING CEMENT PASTES AND MORTARS

Method

33. The quantities of dry materials to be mixed at one time shall be 500 g. for neat cement mixtures and 1000 g. for mortar mixtures. The proportions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be expressed in cubic centimeters (1 cc. of water ≔ 1 g.). The dry materials shall be weighed, placed upon a non-absorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of ½ minute for the absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least one minute. During the operation of mixing, the hands shall be protected by rubber gloves.

Note.—In order to secure uniformity in the results of tests for the time of setting and tensile strength the manner of mixing above described shall be carefully followed. At least one minute is necessary to obtain the desired plasticity which is not appreciably affected by continuing the mixing for several minutes. The exact time necessary is dependent upon the personal equation of the operator. The error in mixing shall be on the side of over mixing.

34. The temperature of the room, the materials, the mixing water, the moist closet and storage-tank water shall be maintained as nearly as practicable at 21°C. (70°Fahr.) and the mixing water, moist closet and the water in the storage tank shall not vary from this temperature more than 3°C. (5°Fahr.).

(X) NORMAL CONSISTENCY

Apparatus

35. The Vicat apparatus consists of a frame *A* (Fig. 1) bearing a movable rod, *B*, weighing 300 g., one end *C* being 1 cm. in diameter for

a distance of 6 cm., the other having a removable needle *D*, 1 mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw *E*, and has midway between the ends a mark *F* which moves under a scale (graduated to millimeters) attached to the frame *A*. The paste is held in a rigid conical ring, resting on a glass plate about 10 cm. square. The ring shall be made of a non-corroding, non-absorbent material, and shall have an inside diameter of 7 cm. at the base, 6 cm. at the top, and a height of 4 cm.

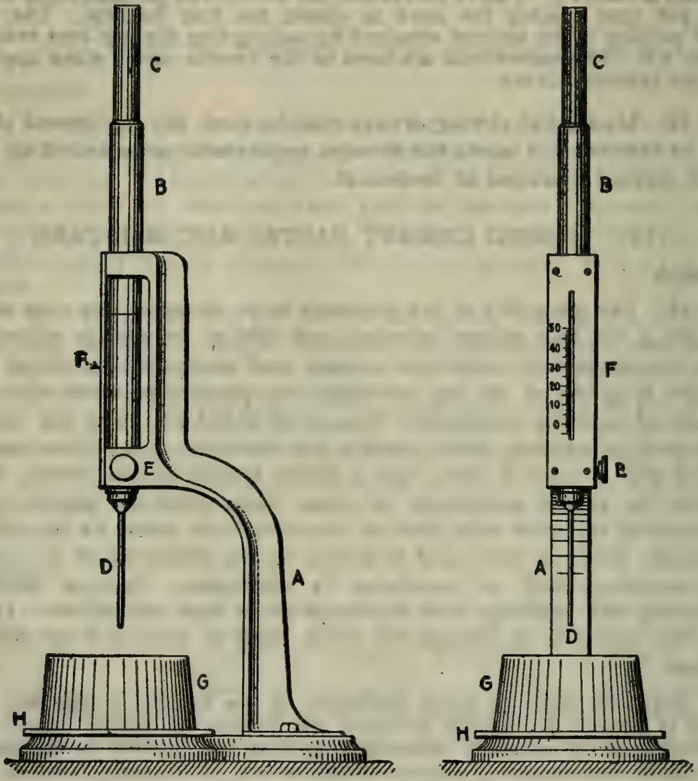


FIG. 1—VICAT APPARATUS

Method

36. In making the determination, 500 g. of cement, with a measured quantity of water, shall be kneaded into a paste, as described in Section 33, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 in. apart; the ball resting in the palm of one hand shall be pressed into the larger end of the conical ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate

and the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring, and the top smoothed, if necessary, with a few light touches of the pointed end of the trowel. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface of the paste; the scale shall then be read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in ½ minute after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency is obtained. Each trial shall be made with fresh cement. The amount of water required shall be expressed in percentage by weight of the dry cement.

37. The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in Table I, the values being in percentage of the combined dry weights of the cement and standard sand.

Table I.—Percentage of Water for Standard Mortars

Percentage of Water for Neat Cement Paste of Normal Consistency	Percentage of Water for One Cement, Three Standard Ottawa Sand	Percentage of Water for Neat Cement Paste of Normal Consistency	Percentage of Water for One Cement, Three Standard Ottawa Sand
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

(XI) DETERMINATION OF SOUNDNESS

Note.—Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking, or disintegration.

Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hours and are not an indication of unsoundness. These conditions are illustrated in Fig. 3.

The failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached does not necessarily indicate unsoundness.

Apparatus

38. A steam apparatus, which can be maintained at a temperature between 98 and 100°C., or one similar to that shown in Fig. 2, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

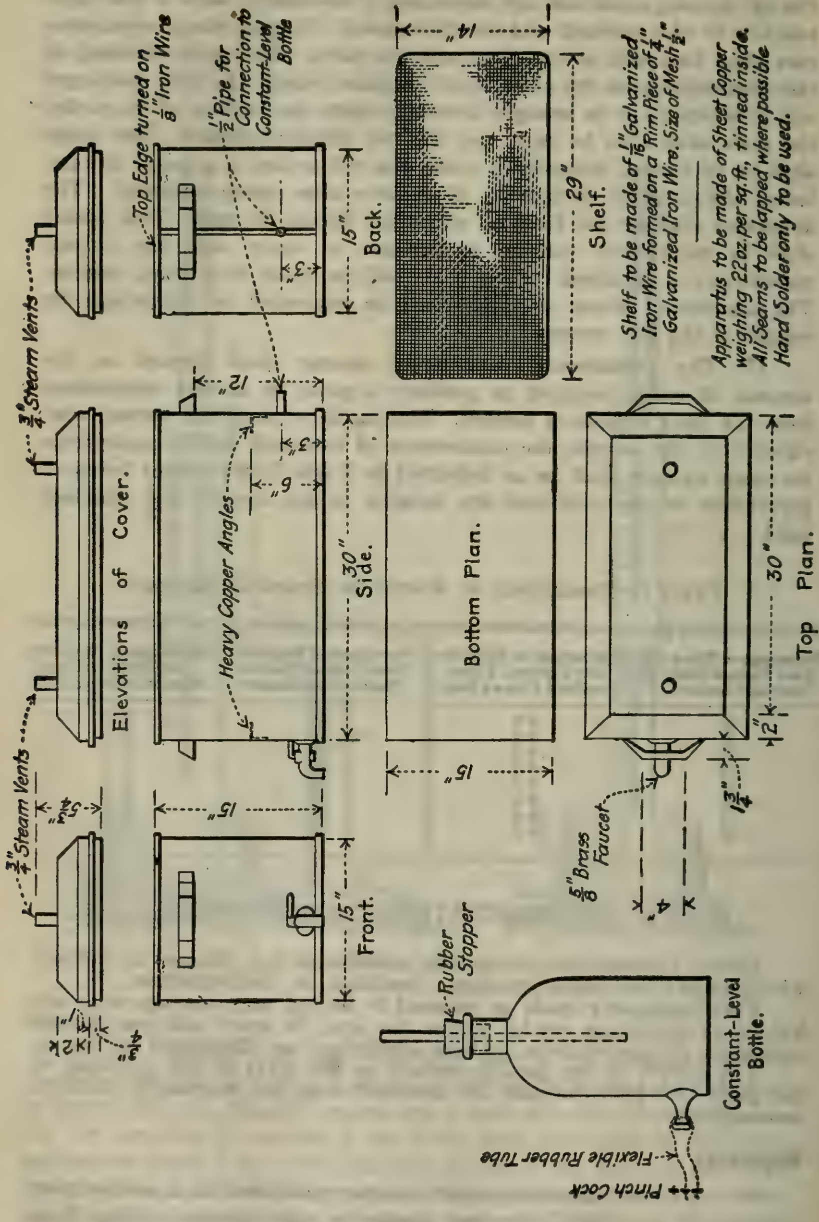

$\frac{3}{4}$" Steam Vents
$\frac{3}{4}$" Steam Vents
$\frac{3}{4}$" Steam Vents
$5\frac{3}{4}$"
2"
1"
$\frac{3}{4}$"
Elevations of Cover.
Top Edge turned on $\frac{1}{8}$" Iron Wire
$\frac{1}{2}$" Pipe for Connection to Constant-Level Bottle
Heavy Copper Angles
15"
Front.
15"
30"
Side.
12"
6"
3"
3"
15"
Back.
Bottom Plan.
15"
14"
29"
Shelf.
Shelf to be made of $\frac{1}{16}$" Galvanized Iron Wire formed on a Rim Piece of $\frac{1}{4}$" Galvanized Iron Wire. Size of Mesh $\frac{1}{2}$".
Apparatus to be made of Sheet Copper weighing 22 oz. per sq. ft., tinned inside. All Seams to be lapped where possible Hard Solder only to be used.
Top Plan.
30"
2"
$1\frac{3}{4}$"
$\frac{5}{8}$" Brass Faucet
4"
Rubber Stopper
Constant-Level Bottle.
Flexible Rubber Tube
Pinch Cock

Fig. 2.—Apparatus for Making Soundness Test of Cement

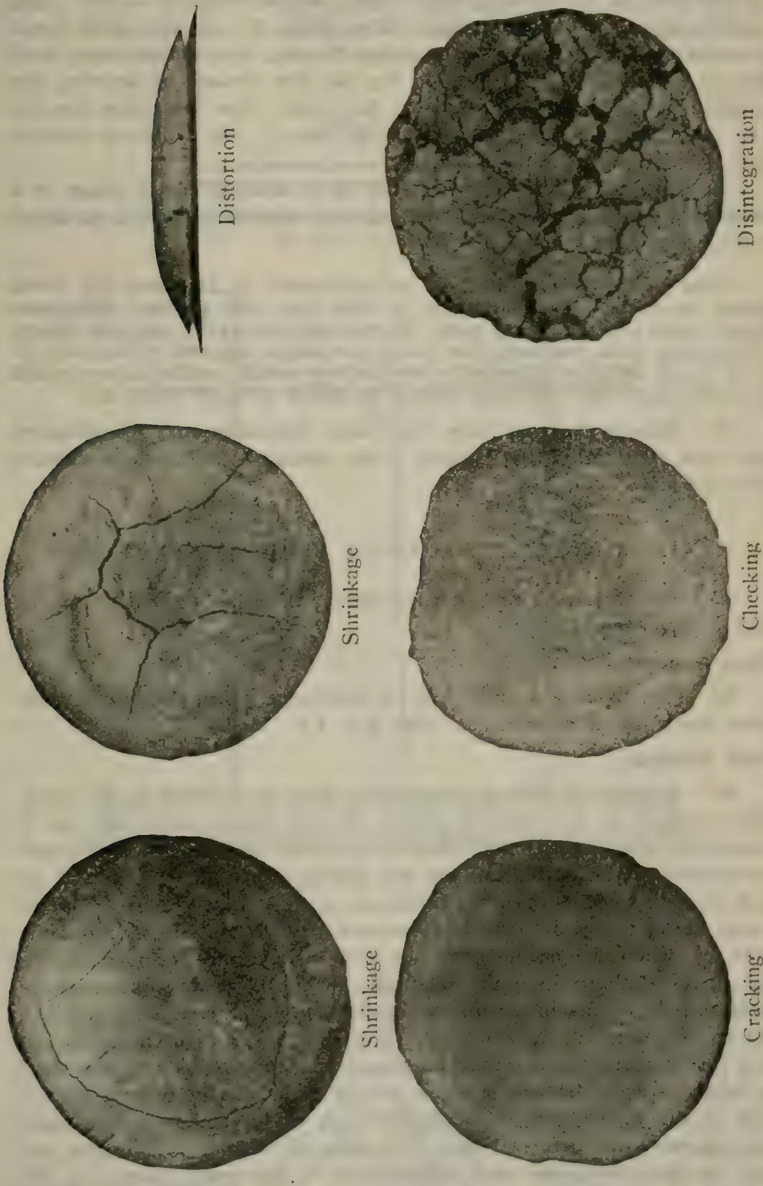


Fig. 3.—Typical Failures in Soundness Test

Method

39. A pat from cement paste of normal consistency about 3 in. in diameter, ½ in. thick at the center, and tapering to a thin edge, shall be made on flat clean glass plates about 4 in. square, and stored in moist air for 24 hours. In molding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center, then flattening the top. The pats used for the time of setting tests by the Gillmore method may be used for soundness tests.

40. The pat shall then be placed in an atmosphere of steam at a temperature between 98 and 100°C., upon a suitable support 1 in. above boiling water for 5 hours.

Note.—It is important that the specimens be 24 hours old when placed in steam, since variations in their age will produce differences in the results of the steam tests. Particularly noticeable are the effects of steaming pats too soon, for many specimens steamed when only 10 or 12 hours old give apparently satisfactory results, while failure would be observed if they were not placed in steam until 24 hours old.

41. Should the pat leave the plate, distortion may be detected best with a straight edge applied to the surface which was in contact with the plate.

(XII) DETERMINATION OF TIME OF SETTING

42. The following are alternate methods, either of which may be used as specified:

Vicat Apparatus

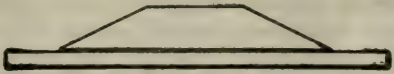
43. The time of setting shall be determined with the Vicat apparatus described in Section 35. (See Fig. 1.)

Vicat Method

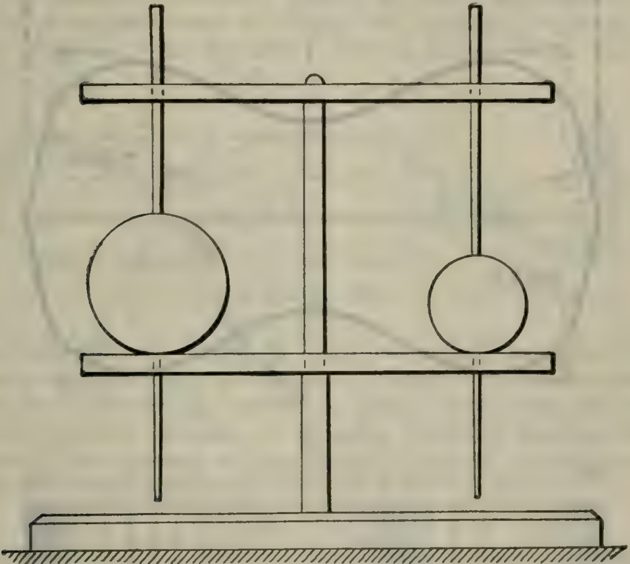
44. A paste of normal consistency shall be molded in the hard-rubber ring *G* as described in Section 36, and placed under the rod *B*, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in ½ minute after being released; and the final set, when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste received, but by the temperature and humidity of the air, and its determination is therefore only approximate.

Gillmore Needles

45. The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in Fig. 4 (*b*), and the needle ends shall be maintained in a clean condition and shall be plane and at right angles to the axis of the rod.



(*a*) Pat with Top Surface Flattened for Determining Time of Setting by Gillmore Method



(*b*) Gillmore Needles
Fig. 4.

Gillmore Method

46. The time of setting shall be determined as follows: A pat of neat cement paste about 3 in. in diameter and ½ in. in thickness with a flat top Fig. 4 (*a*), mixed to a normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21° C. (70° Fahr.). The cement shall be considered to have acquired its initial set when the pat will bear, without appreciable indentation, the Gillmore needle 1/12 in. in diameter, loaded to weigh ¼ lb. The final set has been acquired when the pat will bear, without appreciable indentation, the Gillmore needle 1/24 in. in diameter, loaded to weigh 1 lb. In making the test, the needles shall be held in a vertical position and applied lightly to the surface of the pat.

(XIII) TENSION TESTS

Form of Test Piece

47. The form of test piece shown in Fig. 5 shall be used. The molds shall be made of non-corroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds when used shall be of the type shown in Fig. 6. Molds shall be oiled with a mineral oil.

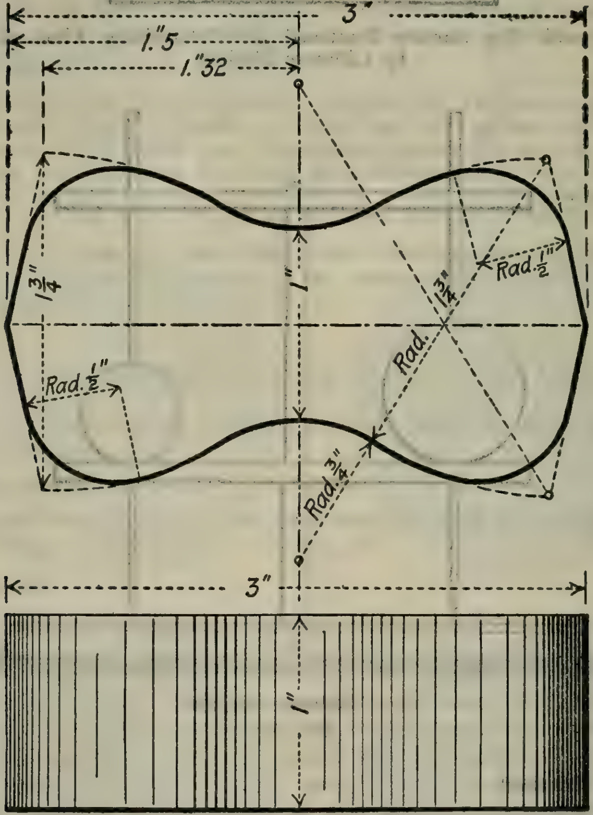


FIG. 5.—DETAILS FOR BRIQUET

Standard Sand

48. The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained from the Ottawa Silica Co., Ottawa, Ill.

49. This sand shall be considered standard when not more than 5 g. are retained on the No. 20 sieve, and not more than 5 g. pass the No. 30 sieve, after one minute continuous sieving of a 100-g. sample,

in the manner specified for sieving cement on the No. 200 sieve (see Section 31).

50. The Nos. 20 and 30 sieves shall conform to the requirements for these sieves as given in the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11).

Molding

51. Immediately after mixing the standard mortar in accordance with the methods for mixing cement pastes and mortars the molds shall be filled heaping full without compacting. Then the mortar shall be pressed in firmly with the thumbs, applying pressure 12 times to each briquet, at points to include the entire surface. The pressure shall be such that the simultaneous application of both thumbs will register a pressure of between 15 and 20 lb. Each application of the thumbs shall be maintained not longer than sufficient to attain the specified pressure. Then the mortar shall be heaped above the mold and smoothed off with a trowel. The trowel shall be drawn over the mold in such a manner as to exert a pressure of not more than 4 lb. The mold shall then be turned over upon a plane plate oiled with mineral oil, and the operation of heaping, thumbing and smoothing off repeated. No ramming or tamping shall be used, nor any troweling in excess of that required to smooth off the specimen.

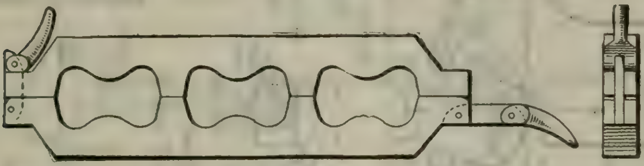
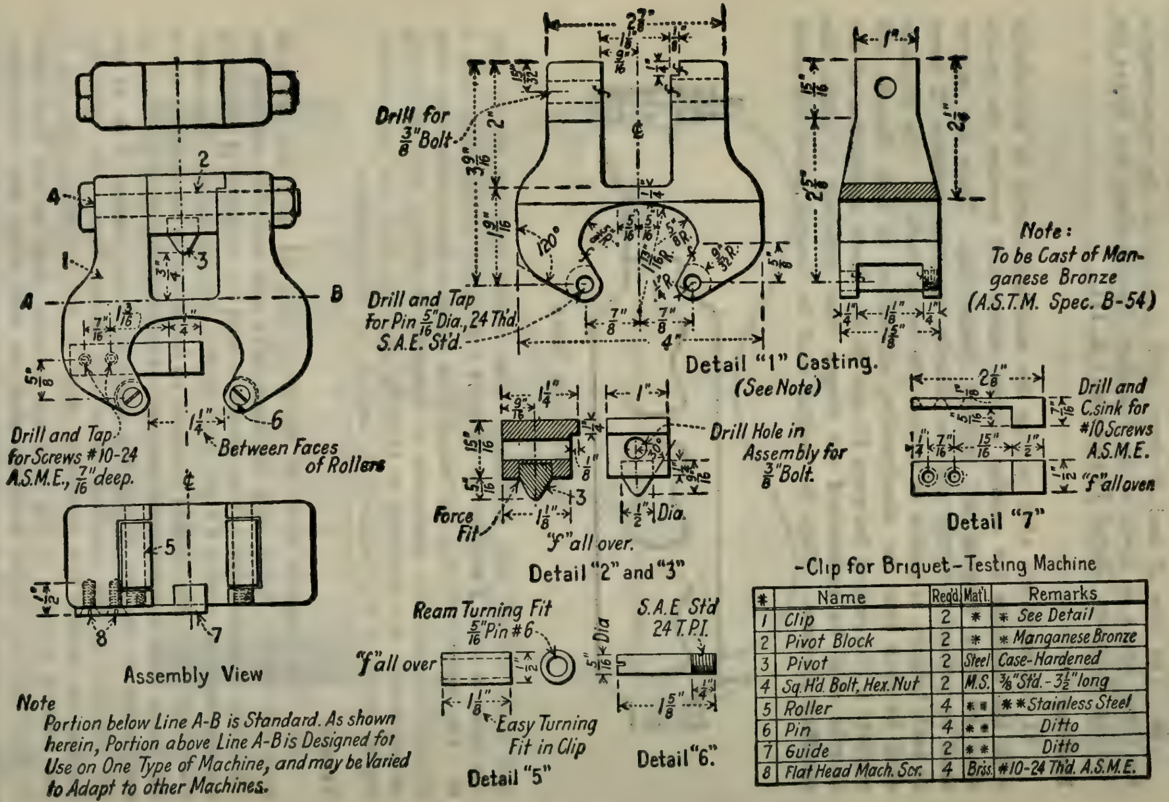


Fig. 6.—Gang Mold

Testing

52. The briquets shall be tested as soon as they are removed from the water. Tests may be made with any machine meeting the following requirements: The machine shall be capable of weighing the applied load within 0.5 per cent of the nominal value. The sensibility reciprocal (the weight required to be added to the load to move the beam from a horizontal position of equilibrium to a position of equilibrium at the top of the trig loop) shall not exceed 1 lb. at the full capacity of the machine or at any lesser load. The clips for holding the tension test specimens shall be in accordance with Fig. 7. The bearing surfaces of the clips and briquets shall be free from sand or dirt, and the roller bearings shall be well oiled and maintained so as to insure freedom of turning. The briquets shall be carefully centered in the clips and the load applied continuously at the rate of 600 lb. per minute.

53. Testing machines shall be frequently calibrated in order to determine their accuracy.



Note: To be Cast of Manganese Bronze (A.S.T.M. Spec. B-54)

Note
Portion below Line A-B is Standard. As shown herein, Portion above Line A-B is Designed for Use on One Type of Machine, and may be Varied to Adapt to other Machines.

-Clip for Briquet-Testing Machine

*	Name	Req'd.	Mat'l.	Remarks
1	Clip	2	*	* See Detail
2	Pivot Block	2	*	* Manganese Bronze
3	Pivot	2	Steel	Case-Hardened
4	Sq. H'd. Bolt, Hex. Nut	2	M.S.	$\frac{3}{8}$" St'd. - $3\frac{1}{2}$" long
5	Roller	4	* *	* * Stainless Steel
6	Pin	4	* *	Ditto
7	Guide	2	* *	Ditto
8	Flat Head Mach. Scr.	4	Brss.	#10-24 Th'd. A.S.M.E.

Fig. 7.—Clip for Briquet Testing Machine

Faulty Briquets

54. Briquets that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test specimens made from the same sample and tested at the same period, shall not be considered in determining the tensile strength.

(XIV) STORAGE OF TEST SPECIMENS

Apparatus

55. The moist closet may consist of a soapstone, slate or concrete box, or a wooden box lined with metal. The interior wall surfaces of all closets shall be covered with felt or broad wicking kept wet. The bottom of the moist closet shall be covered with water to a depth of at least 2 in.

Method

56. All test specimens, immediately after molding, shall be kept in the molds on plane plates in the moist closet for from 20 to 24 hours in such manner that the upper surfaces shall be exposed to the moist air.

57. The briquets shall then be removed from the molds and immersed in clean water in storage tanks constructed of non-corroding material.

[9]SPECIFICATIONS FOR BILLET-STEEL CONCRETE REINFORCEMENT BARS

Material Covered

1. (a) These specifications cover two classes of billet-steel concrete reinforcement bars, namely: plain and deformed.

(b) Plain and deformed bars are of three grades, namely: structural-steel, intermediate and hard.

(c) Twisted bars will not be accepted under these specifications.

Basis of Purchase

2. The structural-steel grade shall be used unless otherwise specified.

(I) MANUFACTURE

Process

3. (a) The steel shall be made by the Open-Hearth process.

(b) The bars shall be rolled from new billets. No rerolled material will be accepted.

(II) CHEMICAL PROPERTIES AND TESTS

Chemical Composition

4. The steel shall conform to the following requirement as to chemical composition:

Phorphorus........................not over .05 per cent.

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[9] Adopted, Vol. 21, 1920, pp. 99, 1361.

Ladle Analyses

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analyses

6. Analyses may be made by the purchaser from finished bars representing each melt of Open-Hearth steel. The phosphorus content thus determined shall not exceed that specified in Section 4 by more than 25 per cent.

(III) PHYSICAL PROPERTIES AND TESTS

Tension Tests

7. (a) The bars shall conform to the following requirements as to tensile properties:

TENSILE PROPERTIES

Properties Considered	Plain Bars			Deformed Bars		
	Structural Steel Grade	Intermediate Grade	Hard Grade	Structural Steel Grade	Intermediate Grade	Hard Grade
Tensile strength lb. per sq. in.	55,000 to 70,000	70,000 to 85,000	80,000 min.	55,000 to 70,000	70,000 to 85,000	80,000 min.
Yield point, min., lb. per sq. in.	33,000	40,000	50,000	33,000	40,000	50,000
Elongation in 8-in. min. %	$\frac{1{,}400{,}000}{\text{Tens. Str.}}$ [a]	$\frac{1{,}300{,}000}{\text{Tens. Str.}}$ [a]	$\frac{1{,}200{,}000}{\text{Tens. Str.}}$ [a]	$\frac{1{,}250{,}000}{\text{Tens. Str.}}$ [a]	$\frac{1{,}125{,}000}{\text{Tens. Str.}}$ [a]	$\frac{1{,}000{,}000}{\text{Tens. Str.}}$ [a]

[a] See Section 8.

(b) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation

8. (a) For plain and deformed bars over $\frac{3}{4}$ inch in thickness or diameter, a deduction of 1 from the percentages of elongation specified in Section 7 (a) shall be made for each increase of $\frac{1}{8}$ inch in thickness or diameter above $\frac{3}{4}$ inch.

(b) For plain and deformed bars under $\frac{7}{16}$ inch in thickness or diameter, a deduction of 1 from the percentages of elongation specified in Section 7 (a) shall be made for each decrease of $\frac{1}{16}$ inch in thickness or diameter below $\frac{7}{16}$ inch.

Bend Tests

9. The test specimen shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

Bend-Test Requirements

Thickness or Diameter of Bar	Plain Bars			Deformed Bars		
	Structural Steel Grade	Intermediate Grade	Hard Grade	Structural Steel Grade	Intermediate Grade	Hard Grade
Under ¾ inch......	180 deg. d=t	180 deg. d=2t	180 deg. d=3t	180 deg. d=t	180 deg. d=3t	180 deg. d=4t
¾ inch or over......	180 deg. d=t	90 deg. d=2t	90 deg. d=3t	180 deg. d=2t	90 deg. d=3t	90 deg. d=4t

Explanatory Note: d=the diameter of pin about which the specimen is bent.
t=the thickness or diameter of the specimen.

Test Specimens

10. Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled.

Number of Tests

11. (a) One tension and one bend test shall be made from each melt, except that if material from one melt differs ⅜ inch or more in thickness or diameter, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(b) If the percentage of elongation of any tension test specimen is less than that specified in Section 7 (a), and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

(IV) PERMISSIBLE VARIATIONS IN WEIGHT

Permissible Variations

12. The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.

(V) FINISH

Finish

13. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

(VI) INSPECTION AND REJECTION

Inspection

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

15. (a) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within five working days from the receipt of samples.

(b) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

16. Samples tested in accordance with Section 6, which represent rejected bars, shall be preserved for two weeks, from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

[10]MASONRY SPECIFICATIONS

It is recommended that railway companies prepare and use specifications complete in themselves for all kinds of masonry, in such form that they may be attached to and form part of specifications and contracts for other railway construction when desirable.

[11]SPECIFICATIONS FOR STONE MASONRY

(I) GENERAL

Standard Specifications

1. The requirements for cement and concrete shall be those adopted by the American Railway Engineering Association.

(II) GENERAL REQUIREMENTS

Stone

2. Stone shall be of .... and shall be sound, hard and durable, of approved quality and shape, free from holes, seams, drys or other imperfections.

Mortar

3. Mortar shall be mixed in a suitable box, or in a machine mixer, preferably of the batch type, and shall be kept free from foreign matter. The size of the batch and the proportions and the consistency shall be as directed by the Engineer. When mixed by hand the sand and cement shall be mixed dry, the requisite amount of water then added and the mixing continued until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

Laying

4. The arrangement of courses and bond shall be as indicated on the drawings, or as directed by the Engineer. Stone shall be laid to exact lines

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[10] Adopted, Vol. 3, 1902, pp. 310, 348.

[11] Adopted, Vol. 7, 1906, pp. 581, 587, 602, 622; Vol. 8, p. 634; Vol. 9, 1908, pp. 650, 655, 659; Vol. 12, Part 1, 1911, pp. 478, 579; Vol. 25, 1924, pp. 660, 1337.

and levels, to give the required bond and thickness of mortar in beds and joints.

5. Stone shall be cleansed and dampened before laying.

6. Stone shall be well bonded, laid on its natural bed and solidly settled into place in a full bed of mortar.

7. Stone shall not be dropped on or dragged over the wall, but shall be placed without jarring stones already laid.

8. Heavy hammering shall not be allowed on the wall after a course is laid.

9. Stone becoming loose after the mortar is set shall be relaid with fresh mortar.

10. Stone shall not be laid in freezing weather, unless authorized by the Engineer. If laid, the stone shall be first freed from ice, snow or frost by warming. The sand and water used in the mortar shall be heated.

Pointing

11. Before the mortar has set in beds and joints, it shall be removed to a depth of not less than 1½ inches. Pointing shall not be done until the wall is complete and mortar set; nor when frost is in the stone.

12. Mortar for pointing shall consist of equal parts of sand, sieved to meet the requirements, and Portland cement. In pointing, the joints shall be wet, and filled with mortar, pounded in with a "set-in" or caulking tool and finished with a beading tool the width of a joint, used with a straightedge.

(III) BRIDGE AND RETAINING WALL MASONRY—ASHLAR STONE

13. The stone shall be large and well-proportioned. The thickness of the courses shall diminish regularly from bottom to top. The maximum thickness shall not be more than twice the minimum thickness and no course shall be less than 12 inches thick.

Dressing

14. Beds and builds shall be square with each other and dressed true and out of wind. They shall be fine-pointed, so that the mortar layer will not be more than ⅜ inch thick when the stone is laid. Hollow beds will not be permitted.

15. Joints in face stone shall be full to the square for a depth equal to at least one-half the height of the course, but in no case less than 10 inches. The backs shall be roughly scabbled to avoid overhang.

Face or Surface

16. Exposed surfaces of the face stone, where not otherwise specified, shall be rock faced with edges pitched to the true lines and exact batter. The face shall not project more than three inches beyond the pitch line.

17. Chisel drafts, not less than 1½ inches wide, shall be cut at exterior edges and shall be neat and accurate.

18. Holes for stone hooks shall not be permitted to show in exposed dressed surfaces. Such stone shall be handled with clams, keys, lewis or dowels.

Stretchers

19. Stretchers shall not be less in length than 2½ times their thickness with an average width of bed at least 1¼ times their thickness.

Headers

20. Headers shall not be less in length than 2½ times their thickness; shall occupy one-fifth of the face of the wall and shall not be less in width than 1¼ times their thickness.

21. Headers shall hold in heart of wall the same size shown in face, so arranged that a header in a superior course shall not be laid over a joint, and a joint shall not occur over a header; the same disposition shall occur in back of wall.

22. Headers in face and back of wall shall interlock when thickness of wall will admit.

23. Where the wall is 3 feet thick or less, the face stone shall pass entirely through. Backing will not be permitted.

Backing

*24-a. At least one-half of the backing stone shall be of the same size as the face stone and be roughly squared; the remainder of backing stone shall be large, well-shaped and roughly bedded and jointed. Bed joints shall not exceed one inch. Vertical joints in back of wall shall not exceed two inches. The interior vertical joints shall not exceed four inches.

Voids shall be thoroughly filled with $\overset{\text{concrete}}{\text{spalls,}}$ fully bedded in cement mortar.

*24-b. Backing shall be of $\overset{\text{concrete}}{\text{headers}}$ and stretchers, as specified in paragraphs 19 and 20, and heart of wall filled with concrete.

25. Where the wall will not admit of such arrangement, stone not less than four feet long shall be placed transversely in heart of wall to bond the opposite sides.

26. Where stone is backed with two courses, neither course shall be less than nine inches thick.

Bond

27. Bond of stone in face, back and heart of wall shall be at least one-half the thickness, but not less than 10 inches. Backing stones shall be laid to break joints with the face stone and with one another.

Coping

28. Coping stone shall be full size throughout, of dimensions indicated on the drawings.

29. Beds, joints and top shall be fine-pointed.

30. Location of joints shall be determined by the position of the bed plates, as indicated on the drawings.

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*Paragraphs 24-a and 24-b are so arranged that either may be eliminated according to requirements.

Locks

31. Where required, coping stones, stones in steps of abutment wings and stones on piers and ice-breakers shall be fastened together with iron cramps or dowels in the position indicated on the drawings.

Ice-Breakers

32. In large piers with ice-breakers, the face of the stones forming the ice-breakers shall have a two-inch tooled margin draft all around, and shall be dressed off between to a minimum surface with a point or pick. The beds and vertical joints shall be pick-dressed the full width of the stones, so as not to exceed ¼ inch in width. The backs of the stones shall be scabbled off so as to form square and vertical joints with the backing. The courses shall be arranged as shown in detail plans.

Trestle Piers

33. Small piers carrying columns shall have backing of precisely the same thickness as the face stones, with beds dressed with the same care. The vertical joints shall be square, and shall not exceed ½ inch in width. Such piers shall be built wholly of dimension stones, and the courses shall be arranged as shown in detailed plans. The footings shall in all cases be of concrete, reinforced, if necessary.

(IV) BRIDGE AND RETAINING WALL MASONRY—BLOCK RUBBLE

34. The stone shall be roughly squared, and may be laid in irregular courses. Beds shall be parallel, roughly dressed, and the stone laid horizontal to the wall. Face joints shall not be more than one-inch thick. Bottom stone shall be large, selected flat stone.

35. The wall shall be compactly laid, having at least one-fifth the surface of back and face headers arranged to interlock, having all voids in the heart of the wall thoroughly filled with concrete suitable stones and spalls, fully bedded in cement mortar.

(V) ARCH MASONRY—ASHLAR STONE

Falsework

36. The Contractor shall provide and erect falsework for the temporary support of arch centers. This may be of any preferred design, subject to approval, but shall be of ample strength and stiffness to safely, and without undue deformation, carry the whole load of completed arch. The Contractor shall be entirely responsible for the stability of the falsework and for any damage that may result from overloading, wind, flood, backwater, logs, ice, fire or other cause. Should piling be necessary, the Railway Company may, at its option, drive the piles at the cost of the Contractor.

Centers

37. The Contractor shall provide and erect centers strongly framed and braced longitudinally and transversely, the upper surface conforming accu-

rately to the curve of the intrados of the arch, after making proper allowance for settlement under load. The lagging shall consist of two-inch by three-inch dressed plank laid transversely along the joints of the voussoir. Arch centers may be of any preferred design (subject to approval). At the ends, and in large arches at the intermediate posts, the centers shall be supported on sills or plates, provided with sand boxes, folding oak or other hardwood wedges, or both. Centers shall not be unequally or eccentrically loaded, and great care shall be taken in striking the arch centers to insure a slow and even subsidence, and to avoid unequal stresses. They shall not be struck without the express permission of the Engineer.

38. Voussoirs or ring stones shall be full size throughout and dressed true to templet, and shall have bond not less than width on intrados.

Dressing

39. Joints of voussoirs and intrados shall be fine-pointed. Mortar joints shall not exceed ¼ inch.

Face or Surface

40. Exposed surface of the ring stone shall be fine-pointed rock-faced with a marginal draft.

41. Number of courses and depth of voussoirs shall be indicated on the drawings.

42. Voussoirs shall be placed in the order indicated on the drawings.

Backing

43. Backing shall consist of concrete large stone, shaped to fit the arch bonded to the spandrel and laid in full bed of mortar.

44. Extrados shall be grouted and finished with 1½-inch coat of mortar applied evenly for a finishing coat, upon which, when required, shall be placed a covering of approved waterproofing material. (For information on Waterproofing, see page 1171, Iron and Steel Structures.)

Bench Walls, Piers, Spandrels, Etc.

45. Bench walls, piers, spandrels, parapets, wing walls and copings shall be built under the specifications for Bridge and Retaining Wall Masonry—Ashlar Stone, as far as applicable.

(VI) ARCH MASONRY—BLOCK RUBBLE

Dressing

46. Voussoirs or ring stones shall be full size throughout, and shall have bond not less than width on intrados.

47. Beds shall be roughly dressed to bring them to radial planes.

48. Mortar joints shall not exceed one inch.

Face or Surface

49. Exposed surfaces of ring stones shall be rock-faced, and edges pitched to true lines.

50. Voussoirs shall be placed in the order indicated on the drawings.

Backing

51. Backing shall consist of $\substack{\text{concrete}\\\text{large stone,}}$ shaped to fit the arch, bonded to the spandrel, and laid in full bed of mortar.

52. Extrados shall be grouted and finished with 1½-inch coat of mortar applied evenly for a finishing coat, upon which, when required, shall be placed a covering of approved waterproofing material. (For information on Waterproofing, see page 1171, Iron and Steel Structures.)

Bench Walls, Piers, Spandrels, Etc.

53. Bench walls, piers, spandrels, parapets, wing walls and copings shall be built under the specifications for Bridge and Retaining Wall Masonry—Block Rubble, as far as applicable.

(VII) CULVERT MASONRY

54. Culvert Masonry shall be laid in cement mortar. Character of stone and quality of work shall be the same as specified for Bridge and Retaining Wall Masonry—Block Rubble.

Side Walls

55. One-half the top stones of the side walls shall extend entirely across the wall.

Cover Stones

56. Cover stones shall be sound and strong and of thickness indicated on the drawings.

57. End walls shall be covered with suitable coping, as indicated on the drawings.

(VIII) DRY MASONRY

58. Dry Masonry shall include dry retaining walls and slope walls.

Retaining Walls

59. Retaining Walls and Dry Masonry shall include all walls in which stone laid without mortar is used for retaining embankments or for similar purposes. Flat stones at least 1½ times as wide as thick shall be used.

60. Bed and joint shall be roughly squared.

61. Bed and face joints shall not exceed one inch. Vertical joints at back two inches and interior joints three inches.

62. Stone of different sizes shall be evenly distributed over entire face of wall, generally keeping the larger stone in lower part of wall.

63. The work shall be well-bonded, and shall present a reasonably true and even surface, free from holes or projections.

Slope Walls

64. Slope walls shall be built of such thickness and slope as indicated on plans or by the Engineer. Stone used in this construction must reach entirely through the wall. Stone shall be placed at right angles to the slopes.

[12]SPECIFICATIONS FOR CONSTRUCTING PRE-MOLDED CONCRETE PILES

1. Piles shall be made in accordance with the dimensions shown on the drawings.

2. The workmanship and materials shall be in accordance with the Specifications for Concrete, Plain and Reinforced, of the American Railway Engineering Association, with the following modifications:

Aggregates

3. The coarse aggregate shall consist of material such as crushed stone or gravel varying in size from ¼ inch to ¾ inch.

Proportions

4. Concrete shall be of such mixture as to give a strength of 3000 lb. per square inch at 28 days.

Curing

5. Where ordinary method of sheltered curing is employed, piles shall be seasoned for a period of not less than three days before being moved and not less than twenty-eight days before handling and moving to the site or driving. No method of accelerated seasoning shall be used until approved by the Engineer.

Marking

6. Each pile shall be stamped or marked with the date of its manufacture.

Handling

7. Piles shall be handled carefully, avoiding any dropping or heavy jarring while in horizontal position.

[13]SPECIFICATIONS FOR DRIVING PRE-MOLDED CONCRETE PILES

1. Piles shall be protected while being driven with an approved cushion cap.

2. The driving or jetting of piles shall be governed by "Pile Driving —Principles of Practice," given in the Specifications for Workmanship for Pile and Frame Trestles in the Manual of the Association.

3. In driving, a steam hammer shall be used unless otherwise specified by the Engineer. Where a drop hammer is permitted, a heavy hammer with a short drop shall be used.

4. Any pile injured in driving or driven out of place shall be either replaced by a new pile or pulled and redriven, as the case may require.

5. On sloping ground, and where necessary, a suitable hole shall be dug at the location of each pile, sufficiently deep to hold the pile in proper position for the first few blows.

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[12] Adopted, Vol. 19, 1918, pp. 725, 1229; Vol. 28, 1927, pp. 1054, 1447.

[13] Adopted, Vol. 19, 1918, pp. 728, 1229; Vol. 25, 1924, pp. 664, 1337; Vol. 28, 1927, pp. 1054, 1447.

6. Before driving, the piles shall be carefully located and set to the line called for on the plan, and the pile driver leads held in proper position by means of guy lines. Unless otherwise called for on the plans, piles shall be driven as nearly as possible in a plumb position. Any pile out of plumb more than one-half inch per foot shall be pulled and redriven if so required by the Engineer.

7. Reasonable efforts shall be made to drive the concrete piles to plan cut-off, the lengths of the piles having been determined by borings or test piles. Driving shall be continued until plan cut-off is reached or until the rate of penetration specified by the Engineer is obtained. (Cases where driving is through soft soil to hard bottom or rock excepted.)

8. When driving is interrupted before final penetration is reached, record for degree of penetration shall not be taken until after at least 2 inches of penetration has been obtained. When necessary to obtain the required penetration, piles may be driven not to exceed 4 inches below plan cut-off.

[14]METHOD OF REPAIRING DEFECTIVE OR WORN SURFACES OF CONCRETE

(1) In all cases the surface to be repaired must first be thoroughly cleaned of all loose material, laitance and dust and the clean, rough, sound concrete exposed to receive the patch. A satisfactory method of cleaning is by means of a steam jet.

(2) After cleaning, the surface to be repaired must be thoroughly saturated with water, not simply moistened, but so thoroughly drenched that the old concrete will not absorb water from the new mortar or concrete used in patching. If possible, the surface should be kept covered with water for several hours.

(3) If the repair or patch is to be made on a vertical or sloping surface and is not to be more than 1½ inches thick, the surface of the old concrete, while it is still wet, should be spattered or splashed with a cement grout, following this immediately with a fairly stiff plaster coat of mortar made of the same proportions of cement and sand as was used in the original concrete, but never richer than 1 cement to 2½ sand. This plaster coat should not be thicker than ½ inch and each coat should be forced into the surface, but not dragged with a trowel. The surface of each coat, except the final coat, should be "scratched" to give a bond for the next coat. This plastering should preferably begin at the top and progress downward, and only enough time be allowed to permit each coat to receive its initial set before the next coat is applied. The final coat should be finished with a wooden float and only enough water used to properly finish the surface. This patch should be kept damp and protected from sun or frost till fully set up.

(4) If the repair or patch or "finish coat" is to be made on a horizontal or nearly horizontal surface, the surface of the old concrete should be slushed and broomed with a thin cement grout, following this immediately with a *wet* mortar made of 1 part cement and 2½ parts sand or granite screenings and of the full thickness required (not less than ½ inch thick,

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[14] Adopted, Vol. 13, 1912, pp. 476, 991-992.

however). When this mortar begins to take its initial set, it should be floated or troweled to such a finish as may be desired.

(5) If the repair or patch is to be made on a vertical or sloping face and is to be more than 1½ inches thick, it will be advisable to embed dowels into the old concrete, as deeply as the thickness of the proposed patch, and spaced sufficiently close together to firmly anchor the patch to the old concrete. The dowels must be wedged into the old concrete and it will be advisable to fasten wires, metal fabrics or bars to the dowels in the case of extensive patching, as an additional safeguard. The patching may then be done with mortar without forms, or with wet concrete supported by forms, depending upon the thickness and the extent of the patch.

(6) If the repair or patch is to be made on a horizontal or nearly horizontal face and of considerable thickness, dowels may be used, or the concrete may simply be reinforced by fabric or bars without using dowels—treating the patch as a block of masonry.

(7) Care must be taken not to have thin edges on patches. To avoid this, it may be necessary to cut out sound concrete around a place to be patched, so as to give deep edges to the patch. If possible, the edges should be undercut.

Appendix A

PLAIN AND REINFORCED CONCRETE

Figures

For explanation of symbols used in figures, see notations in specifications.

(Sections 1 to 135)

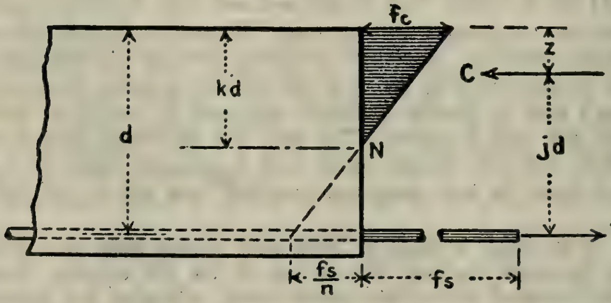


FIG. 1—Nomenclature for Concrete Beam Reinforced for Tension

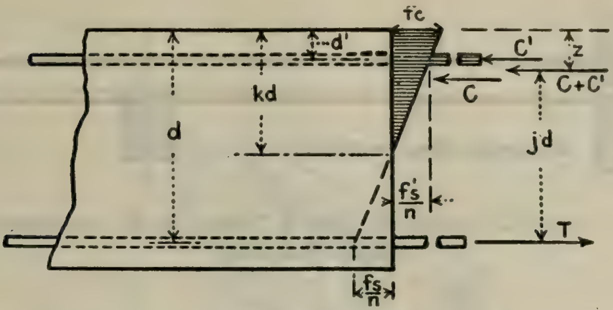


FIG. 2—Nomenclature for Concrete Beam Reinforced for Tension and Compression

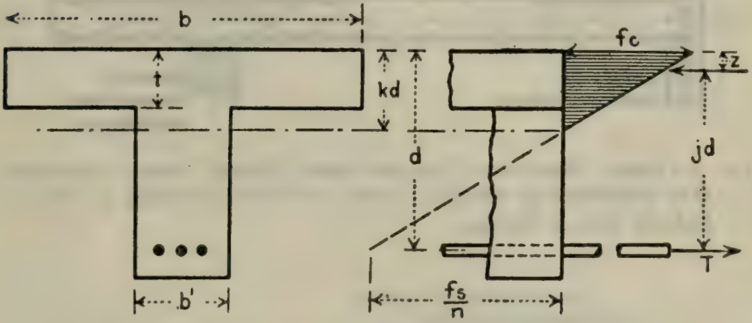


FIG. 3—Nomenclature for Reinforced Concrete T-Beam

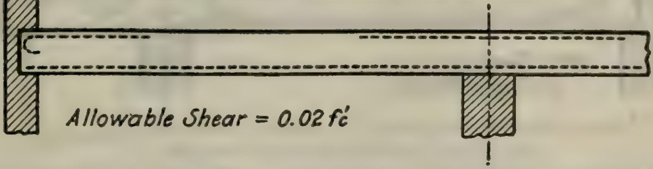


FIG. 4—Typical Reinforced Concrete Beam; Principal Longitudinal Bars Without Special Anchorage

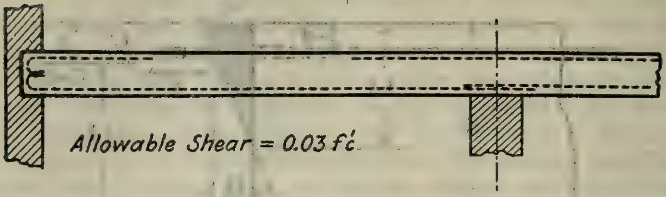


FIG. 5—Typical Reinforced Concrete Beam; Special Anchorage of Longitudinal Bars

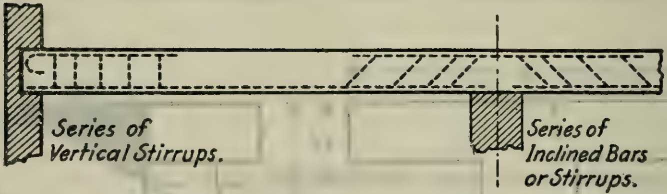


FIG. 6—Typical Reinforced Concrete Beam Without Special Anchorage; Web Reinforced by Means of Series of Vertical Stirrups or Series of Inclined Bars or Stirrups

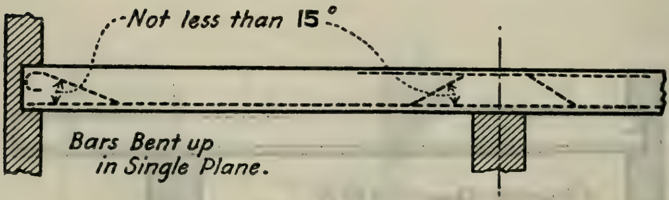


FIG. 7—Typical Reinforced Concrete Beam; Principal Longitudinal Bars Bent Up in Single Plane

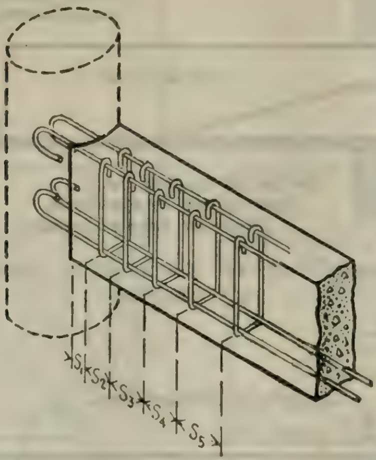


FIG. 8—Typical Reinforced Concrete Beam with Anchored Longitudinal Bars and Vertical Stirrups

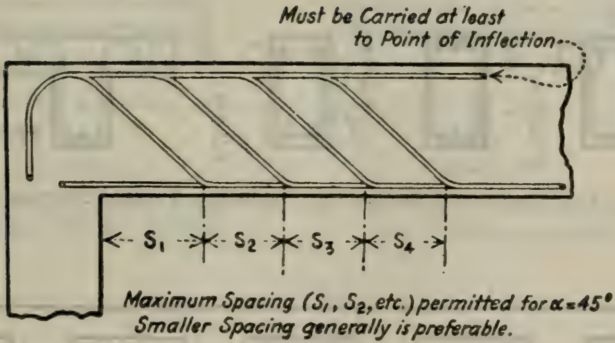

Must be Carried at least
to Point of Inflection
S1
S2
S3
S4
Maximum Spacing (S1, S2, etc.) permitted for α=45°
Smaller Spacing generally is preferable.

FIG. 9—Typical Beam With Web Reinforced by Means of Series of Inclined Bars

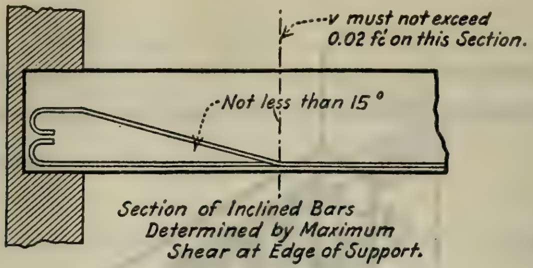


FIG. 10—Typical Beam With Web Reinforced by Means of Bars Bent Up in Single Plane

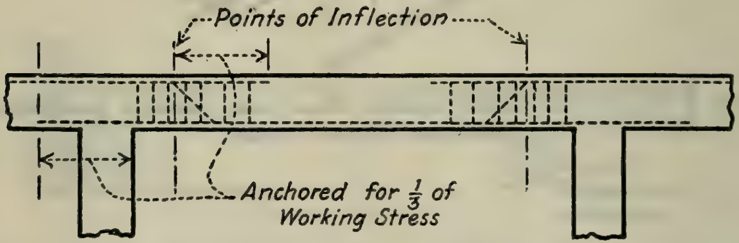


FIG. 11—Typical Web Reinforcement for Continuous Beams With Special Anchorages

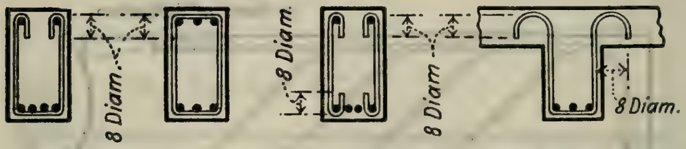


FIG. 12—Typical Methods of Anchoring Vertical Stirrups

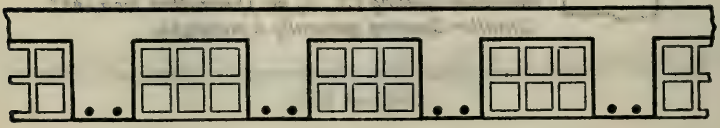
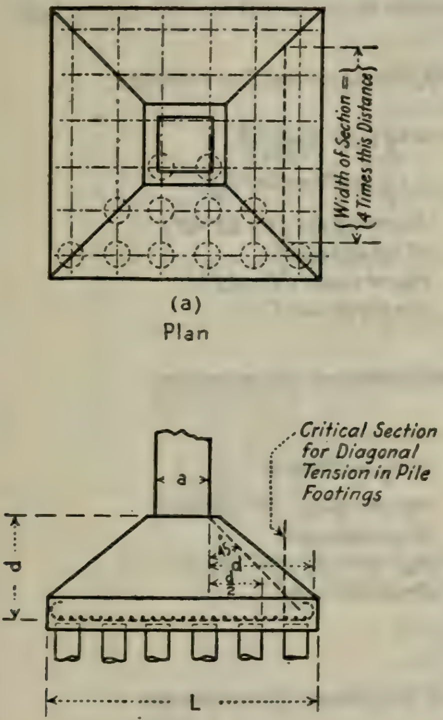


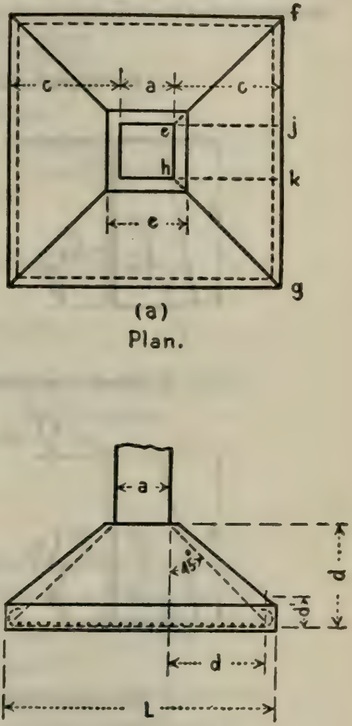
FIG. 13—Typical Reinforced Concrete Beam-and-Tile Construction


Width of Section = 4 Times this Distance
Critical Section for Diagonal Tension in Pile Footings
a
d
45°
d/2
y
L

(a)
Plan

(b)
Elevation.

Fig. 14—Typical Sloped Reinforced Concrete Footing on Piles



(a)
Plan.

(b)
Elevation.

Fig. 15—Typical Sloped Reinforced Concrete Footing on Soil

Appendix B

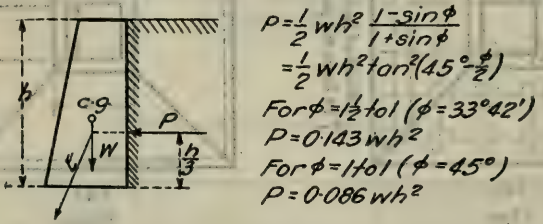
RETAINING WALLS

Figures, Formulæ and Principles of Design

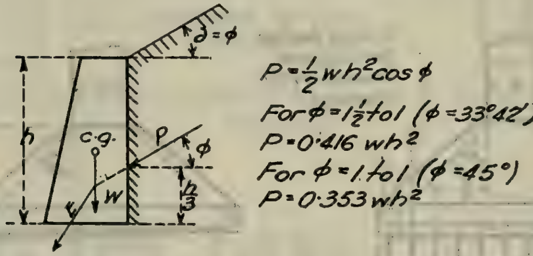
For Specifications, see Sections 136, 140.

The height of surcharge loading will be equal to the load per linear foot divided by b ($b = 14$ feet for a single track railway). Where the edge of the distributed load cannot come nearer to the vertical line through the back of the heel of the wall than $h - x$, the equivalent uniformly distributed load in terms of height is

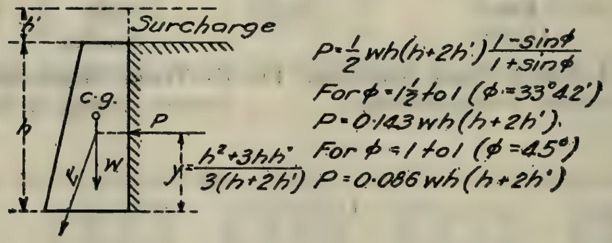
1 Vertical Wall, Horizontal Surcharge


h
c.g.
W
P
$\frac{h}{3}$
$P = \frac{1}{2} wh^2 \frac{1-\sin\phi}{1+\sin\phi}$
$= \frac{1}{2} wh^2 \tan^2(45° - \frac{\phi}{2})$
For $\phi = 1\frac{1}{2}$ to 1 ($\phi = 33°42'$)
$P = 0{\cdot}143\, wh^2$
For $\phi = 1$ to 1 ($\phi = 45°$)
$P = 0{\cdot}086\, wh^2$

2 Vertical Wall, Sloping Surcharge


$\delta = \phi$
h
c.g.
W
P
ϕ
$\frac{h}{3}$
$P = \frac{1}{2} wh^2 \cos\phi$
For $\phi = 1\frac{1}{2}$ to 1 ($\phi = 33°42'$)
$P = 0{\cdot}416\, wh^2$
For $\phi = 1$ to 1 ($\phi = 45°$)
$P = 0{\cdot}353\, wh^2$

3 Vertical Wall, Loaded Surcharge

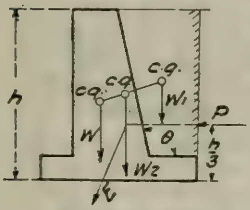

h'
Surcharge
h
c.g.
W
P
$y = \frac{h^2 + 3hh'}{3(h+2h')}$
$P = \frac{1}{2} wh(h+2h') \frac{1-\sin\phi}{1+\sin\phi}$
For $\phi = 1\frac{1}{2}$ to 1 ($\phi = 33°42'$)
$P = 0{\cdot}143\, wh(h+2h')$
For $\phi = 1$ to 1 ($\phi = 45°$)
$P = 0{\cdot}086\, wh(h+2h')$

$$h_x' = h^1 \frac{x}{h}$$

Inclined Walls

(a) For walls leaning forward or walls with the base extending into the filling the pressure of the filling on a vertical plan through back of the heel of the wall is to be combined with the wedge of filling contained between this vertical plane and the back of the wall.

4. Wall Leaning Forward, Horizontal Surcharge



$P = \frac{1}{2} w h^2 \frac{1-\sin\phi}{1+\sin\phi}$

$= \frac{1}{2} w h^2 \tan^2(45° - \frac{\phi}{2})$

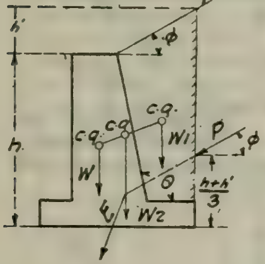
as in Case 1.

W = total weight of wall one ft. long.

W_1 = " " earth wedge " " "

$W_2 = W + W_1$.

5. Wall Leaning Forward, Inclined Surcharge



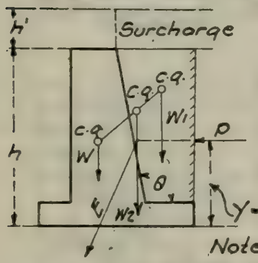
$P = \frac{1}{2} w (h+h')^2 \cos\phi$

W = total weight of wall one ft. long

W_1 = " " earth wedge " " "

$W_2 = W + W_1$

6. Wall Leaning Forward, Loaded Surcharge



h' = surcharge per sq. ft. ÷ w.

$P = \frac{1}{2} w h (h+2h') \frac{1-\sin\phi}{1+\sin\phi}$

as in case 3

W = total weight of wall one ft. long

W_1 = " " earth wedge " " "

$W_2 = W + W_1$

$Y = \frac{h^2 + 3h'h}{3(h+2h')}$

Note: Wall should be investigated when W_1 includes surcharge, and when surcharge over wedge is omitted.

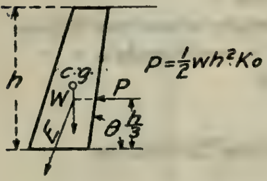
(b) For walls leaning toward the filling the resultant pressure P will be horizontal for a wall without surcharge or with a horizontal loaded surcharge, and will make an angle λ with the horizontal for a wall with a sloping surcharge. The values of λ will vary from δ, where the wall is vertical, to zero, where Rankine's Theory shows that the resultant pressure is horizontal.

DISCUSSION OF FORMULAS FOR RETAINING WALLS

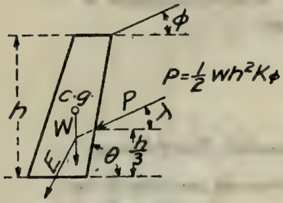
Cases 1 to 3 are for vertical walls without heels. The pressure P is the same as the pressure on a vertical plane in the filling. Vertical walls with heels come under Cases 4 to 6. (See Appendix B.)

Cases 4 to 6 are for walls with heels. The wall may be vertical or may lean forward, or may lean backward as long as the upper edge of the back of the wall is in front of the vertical plane through the edge of the heel.

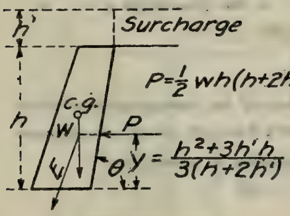
7·Wall Leaning Toward the Filling, Horizontal Surcharge

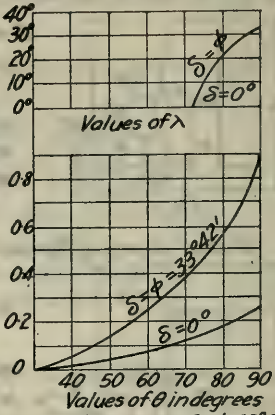


8·Wall Leaning Toward the Filling, Inclined Surcharge

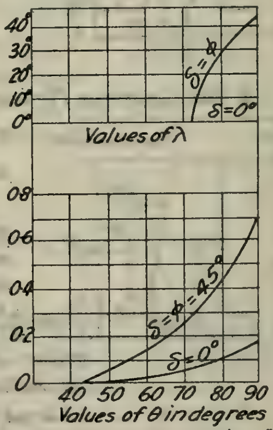


9·Wall Leaning Toward the Filling·Loaded Surcharge





10·Values of Ko and Kφ for φ=33°42'

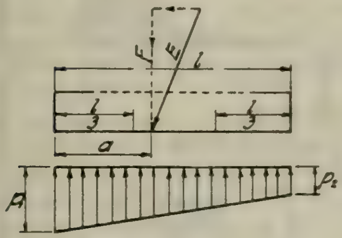


11·Values of Ko and Kφ for φ= 45

Cases 7 to 9 are for walls without heels. Walls with heels come under Cases 4 to 6 as long a sthe upper edge of the back of the well is in front of the vertical through the edge of the heel; if the upper edge of the back of the wall extends back of the vertical plane through the edge of the heel, the problem can be solved by combining the solutions of Cases 4 to 6 and 7 to 9.

Values of λ and values of K where $P = \frac{1}{2} wh^2 K$ are given in Fig. 10 and 11.

12 Pressures on Foundation. Resultant within Middle Third.

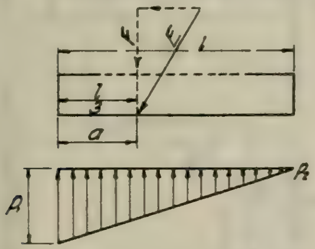


$$p_1 = (4l - 6a)\frac{F}{l^2}$$

$$p_2 = (6a - 2l)\frac{F}{l^2}$$

$$\text{when } a = \frac{l}{2},\ p_1 = p_2 = \frac{F}{l}$$

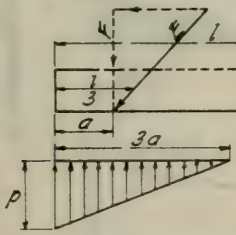
13 Pressures on Foundation, Resultant at edge of Middle Third.



$$p = (4l - 6a)\frac{F}{l^2} = \frac{2F}{l}$$

$$p_2 = (6a - 2l)\frac{F}{l^2} = 0$$

14 Pressures on Foundation, Resultant outside Middle Third.



$$p = \frac{2F}{3a}$$

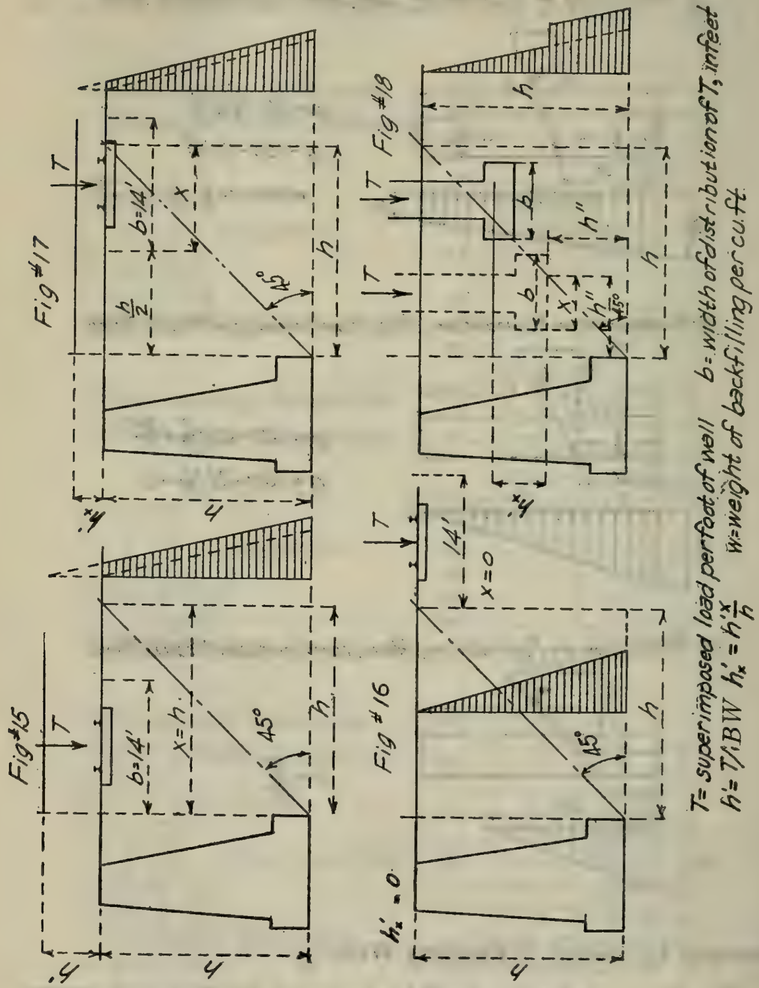
Principles for Design of Retaining Walls

The following principles should be observed in the design and construction of retaining walls.

(1) For usual conditions of the filling, use an angle of repose of 1½ to 1 ($\phi = 33° 42'$). For dry sand or similar material, a slope of 1 to 1 ($\phi = 45°$) may be used.

(2) The maximum pressure at the toe of the retaining wall should never exceed the safe bearing pressure on the material considered.

(3) When the retaining wall rests on a compressible material, where settlement may be expected, the resultant thrust E should strike at the middle or back of the middle of the base of the wall so that the wall will settle toward the filling $\left(a = \text{or} > \frac{l}{2}\right)$.



T = superimposed load per foot of wall b: width of distribution of T, in feet

$h' = T/BW$ $h'_x = h'\frac{x}{h}$ w: weight of backfilling per cu. ft.

(4) When the retaining wall rests on material where settlement may not be expected the resultant thrust E should not strike outside the middle third of the base $\left(a = \text{or} > \frac{l}{3}\right)$, except as noted in (5) below.

(5) Where the retaining wall rests on solid rock or is carried on piles the resultant thrust E may strike slightly outside the middle third, provided

the wall is safe against overturning, and also provided the maximum allowable pressure is not exceeded, but in no case shall the righting moment be less than 1½ times the overturning moment.

(6) In order that the retaining wall may be safe against sliding, the frictional resistance of the base, combined with the abutting resistance of the earth in front of the wall, must be greater than the horizontal thrust on the back of the wall.

(7) The filling back of the wall should be carefully drained so that the wall may not be subjected to hydrostatic pressure.

(8) The foundation for a retaining wall should always be placed below frost line.

(9) A careful study should be made of the conditions in the design of each wall, and it should be remembered that no theoretical formulas can be more than an aid to the judgment of the experienced designer. The main value of theoretical formulas is in obtaining economical proportions, in obtaining a proper distribution of the stresses, and in making experience already gained more valuable.

COMMITTEE IX

GRADE CROSSINGS

[1]SPECIFICATIONS FOR HIGHWAY GRADE CROSSINGS AND APPROACHES OTHER THAN THOSE FOR WHICH REQUIREMENTS ARE STIPULATED BY LAW

1. A railroad grade crossing should be so constructed that it will not limit the traffic on a highway, in respect to the number of vehicles or load carried by the highway.

2. The grade of the surface of the highway should be level with the top of the near rail for a distance of one foot outside thereof; should be 3 inches lower 10 feet outside of the rail; and should be not more than 3 inches higher nor 9 inches lower than the top of the rail at points 30 feet from it, measured at right angles thereto. The grade beyond these 30-foot points should not exceed that which prevails in the section of the country for highways of the class under consideration (Fig. 1).

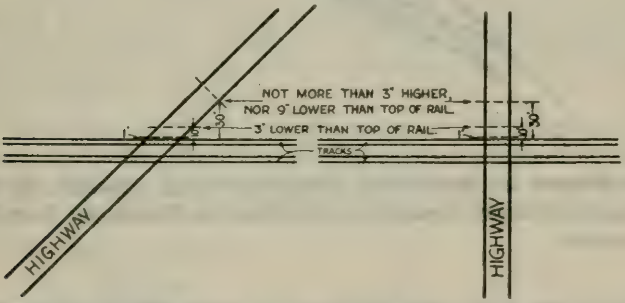


FIG. 1—METHOD OF FIXING APPROACH GRADES FOR HIGHWAY CROSSINGS AS DESCRIBED IN PARAGRAPH 2 OF SPECIFICATIONS

3. When a highway crosses a railroad at an angle less than a right angle, consideration should be given to changing the alinement of the highway, so that the portion within the limits of the railroad right-of-way will be at right angles to the track (Fig. 2).

4. The width of embankments at the crown, and of cuts exclusive of ditches, should be not less than 20 feet.

5. Ample drainage for track and highway should be provided.

6. A crossing should be constructed with continuous surface between points not less than 8 inches outside of each rail. The surface should be not

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[1] Adopted, Vol. 24, 1923, pp. 122, 1141.

more than ¼ inch below the top of the rail and should be beveled at each end. Flangeways 2¼ inches wide should be provided on straight track and on curves of 8 degrees and under, and 2½ inches wide on curves in excess of 8 degrees. They should be flared at the ends to 3½ inches. As far as it may be practicable to avoid them, there should be no rail joints within the limits of the crossing.

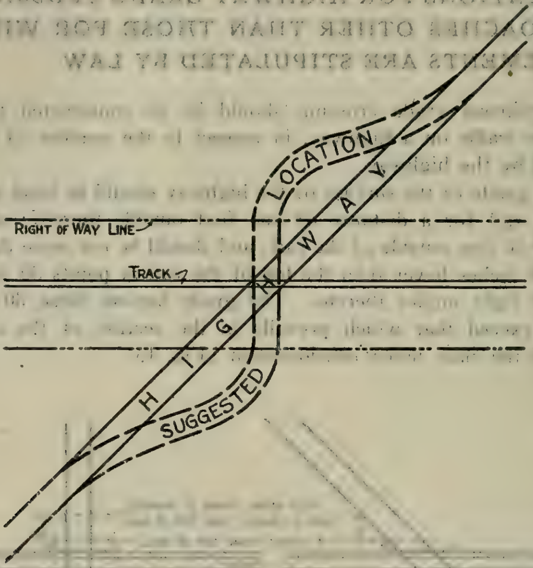

FIG. 2—METHOD OF RELOCATING HIGHWAY GRADE CROSSING TO CROSS TRACKS AT RIGHT ANGLES, AS SUGGESTED IN PARAGRAPH 3 OF SPECIFICATIONS

[2]PRINCIPLES FOR DETERMINING THE RELATIVE BENEFITS TO THE PUBLIC AND RAILROADS FROM:

(a) Grade Crossing Protection
(b) Elimination of Grade Crossings
(c) Reduction of Traffic on Highway Grade Crossings

1. In determination of the relative benefits to the public and railroad from (a) protection of highway grade crossings, (b) elimination of highway grade crossings, and (c) reduction of traffic on highway grade crossings, consideration should be given to the following general principles:

(a) Creation of new grade crossings should be avoided.

(b) In the construction and improvement of highways and railroads, provision should be made for the elimination of existing highway grade crossings, including crossings of local roads where the road traffic can be diverted to the main highways.

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[2] Adopted, Vol. 30, 1929, pp. 506, 1425.

(c) Plans and agreements for highway crossing separations should provide for the abandonment and closing of the existing grade crossings carrying the same highway traffic.

(d) Where the expense of grade crossing elimination or separation is not justified, protection should be provided. The character of protection should depend upon local conditions and the character and volume of traffic.

(e) Increasing need for grade crossing protection is brought about principally by change in character and increase in volume of highway traffic. The benefit from such protection will accrue in greater proportion to users of the highway and the cost should be shared accordingly by state and municipal authorities.

(f) The elimination or protection of highway grade crossings is of such importance, and involves the public safety to such an extent, that primary consideration should be given to such improvements in the allocation of capital by the railroads for safety measures designed to protect the public, and also in the allocation of funds made available by the Federal aid act and other legislation for highway improvements.

(g) The order in which grade crossing elimination projects should be undertaken depends upon many varying factors, and should be fixed by a study of the local conditions at each crossing, care being taken to see that the greatest safety and expedition in the movement of traffic are secured for the money expended. Primary consideration should be given to the elimination of grade crossings at which extra hazard exists by reason of traffic and physical conditions.

2. The relative benefits to the public and railways from grade crossing protection, elimination, or reduction of traffic must be arrived at in the light of reasoned judgment, having in view all the conditions and factors affecting the particular crossing. Among the elements to be considered are:

(a) Physical conditions:

1. Alinement.
2. Grades.
3. Visibility.
4. Drainage.
5. Character and cost of highway and railroad construction.

(b) Railroad traffic:

1. Number and speed of trains.

(c) Highway traffic:

1. Number of pedestrians.
2. Number of automobiles.
3. Number of trucks.
4. Number of horse drawn vehicles.
5. Relative proportion of local and through highway traffic.

(d) Federal and state laws and regulations.

3. The necessity for sincere co-operation between railroad and highway officials in the consideration of grade crossing problems should be emphasized.

[3]HIGHWAY CROSSING SIGNS

Signs for use at highway grade crossings are:

Advance Warning Sign, Fig. 6. To be placed in advance of crossing from 100 to 300 feet distant, as may be required by local conditions.

Highway Crossing Sign, Fig. 3. To be used as required by law or where manual or automatic protection is not provided.

Flashlight Signal, Fig. 4, or Wigwag Signal, Fig. 5. To be used at busy crossings and to replace gates and watchmen.

At crossings where wigwag or flashlight signals are used, one should be placed on each side of the track. In cities and towns where the street is of sufficient width, signals should be located in the center of the street. (See Fig. 4 and 5.)

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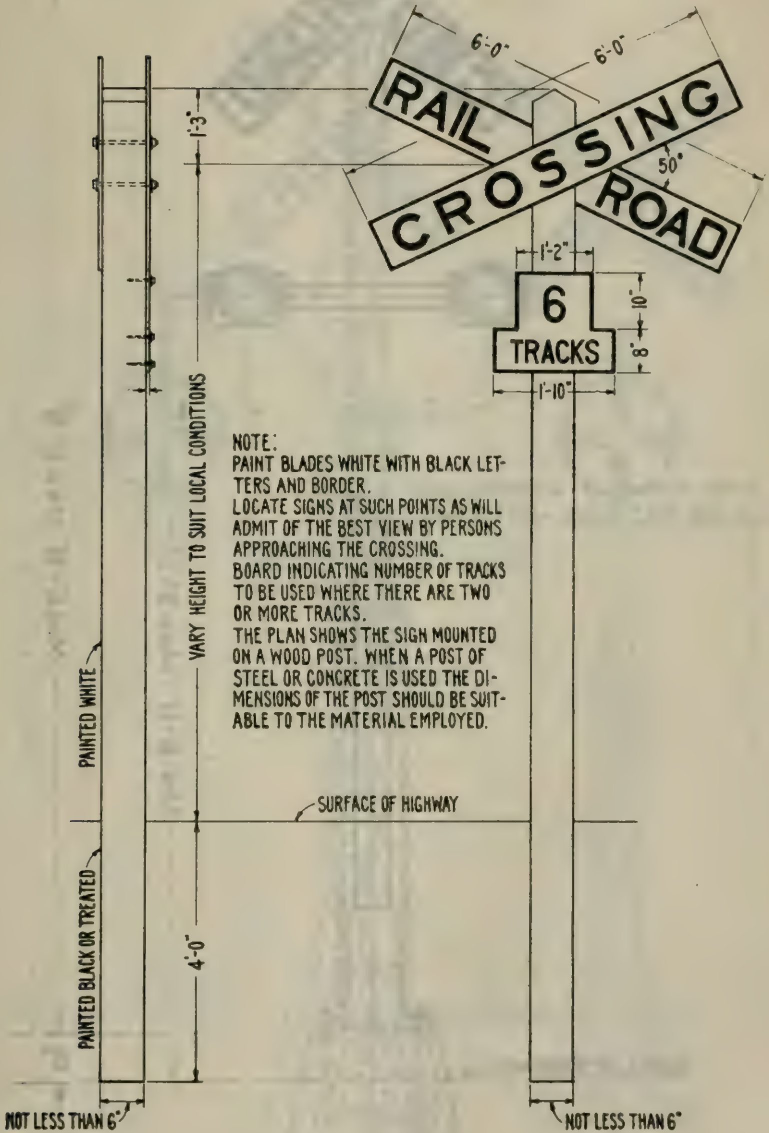
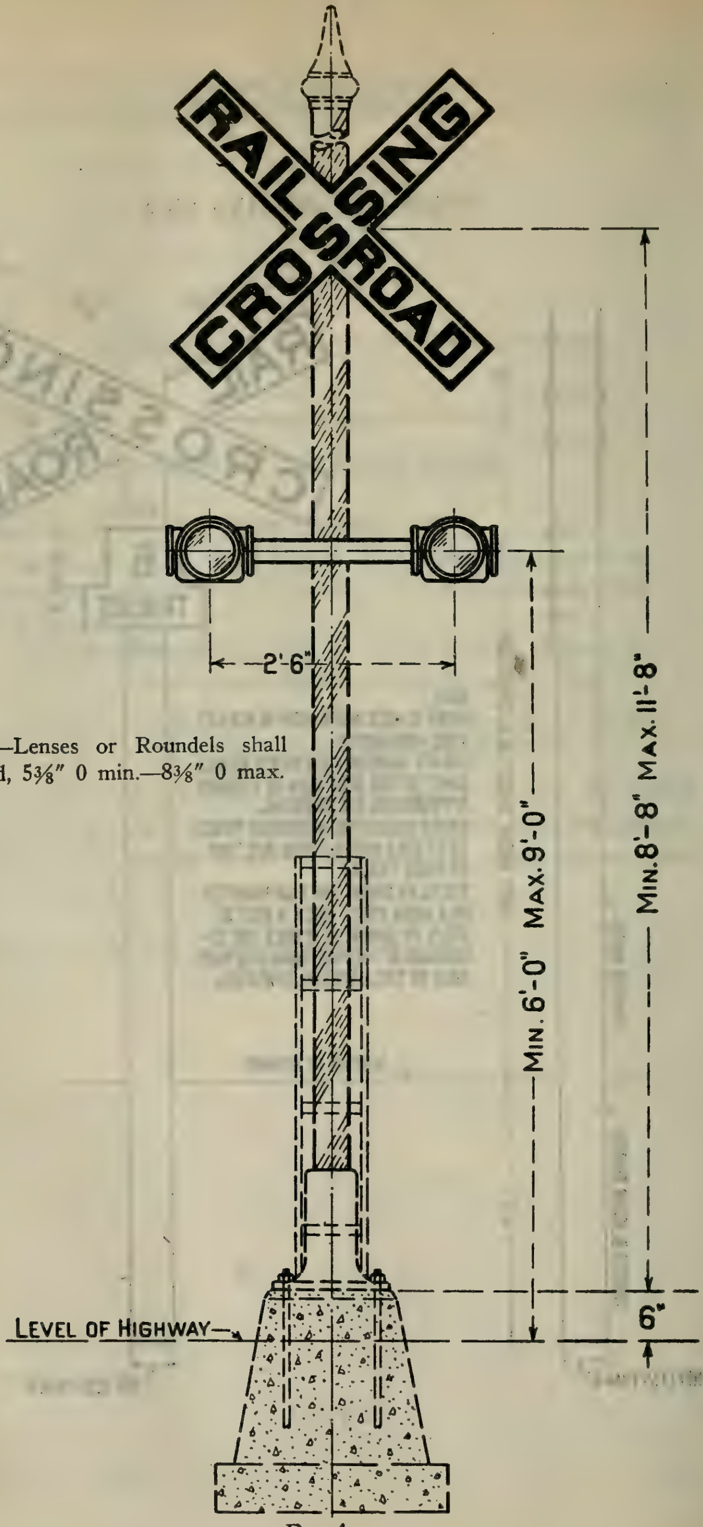
[3] Adopted, Vol. 30, 1929, pp. 496, 1418, 1421.

HIGHWAY CROSSING SIGN



NOTE:
PAINT BLADES WHITE WITH BLACK LETTERS AND BORDER.
LOCATE SIGNS AT SUCH POINTS AS WILL ADMIT OF THE BEST VIEW BY PERSONS APPROACHING THE CROSSING.
BOARD INDICATING NUMBER OF TRACKS TO BE USED WHERE THERE ARE TWO OR MORE TRACKS.
THE PLAN SHOWS THE SIGN MOUNTED ON A WOOD POST. WHEN A POST OF STEEL OR CONCRETE IS USED THE DIMENSIONS OF THE POST SHOULD BE SUITABLE TO THE MATERIAL EMPLOYED.

Fig. 3



Note.—Lenses or Roundels shall be: red, 5⅜" 0 min.—8⅜" 0 max.

Fig. 4

HIGHWAY CROSSING SIGNAL—WIGWAG

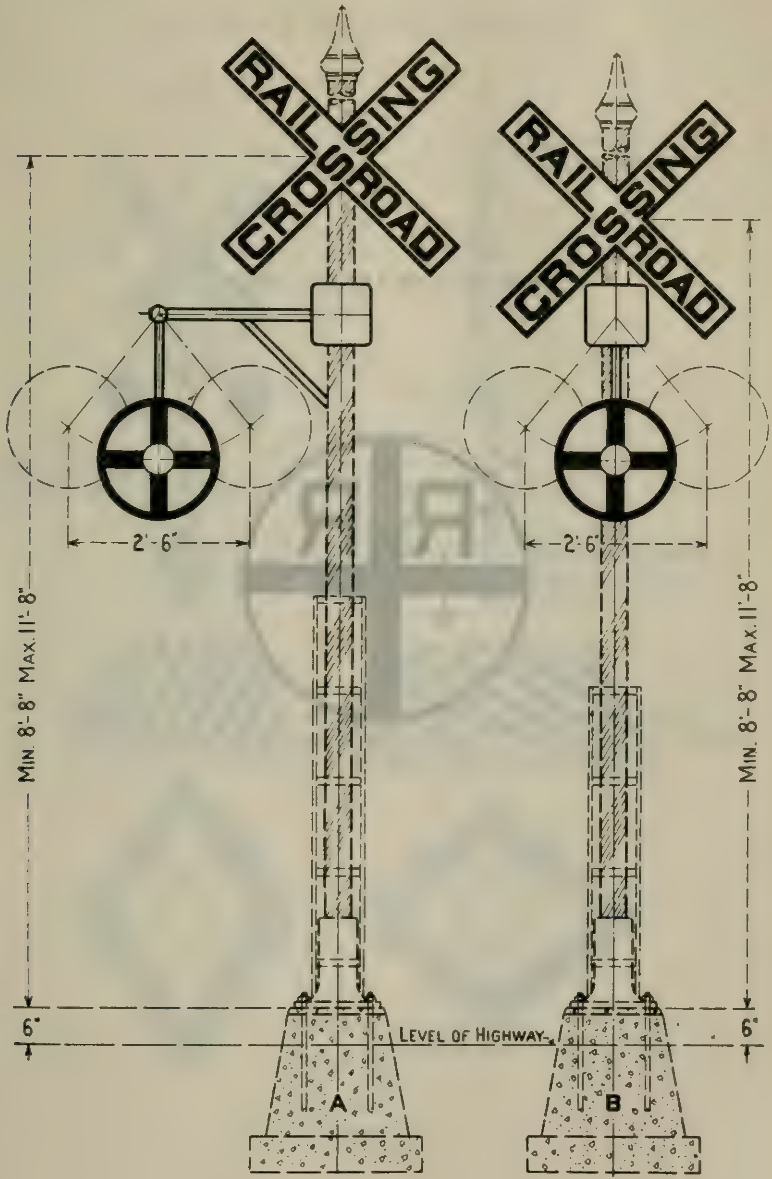


FIG. 5

ADVANCE WARNING SIGN

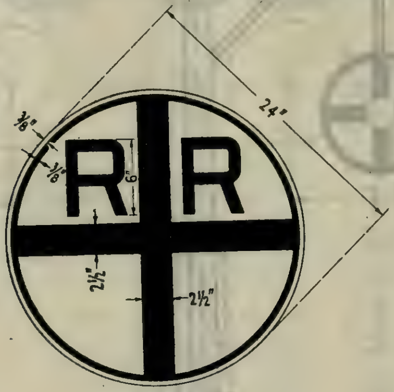


Fig. 6

CENTER OF ROAD INSTALLATION

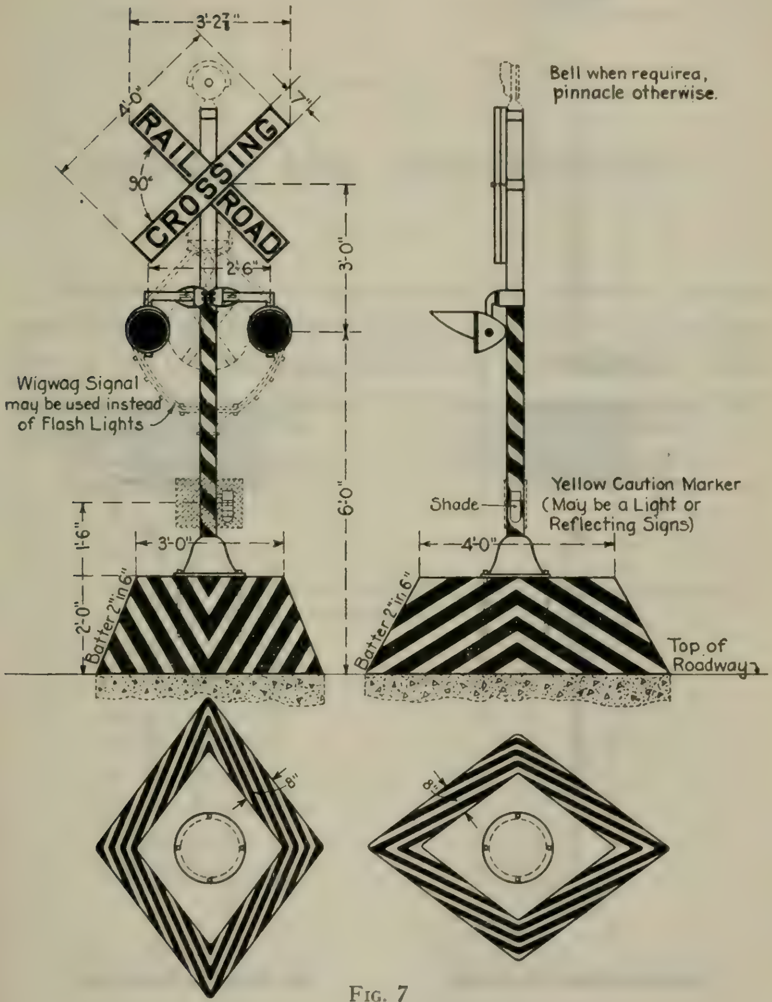
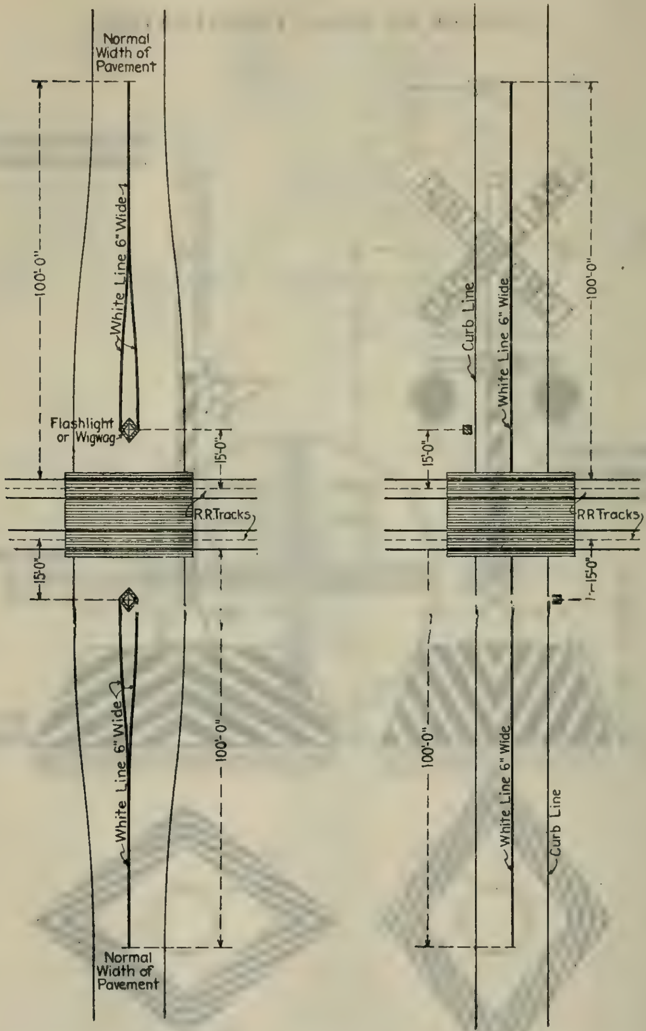

3'-2 7/8"
4'-0"
7"
90°
RAILROAD
CROSSING
2'-6"
3'-0"
6'-0"
Wigwag Signal may be used instead of Flash Lights
1'-6"
2'-0"
3'-0"
Batter 2" in 6"
Bell when required, pinnacle otherwise.
Yellow Caution Marker (May be a Light or Reflecting Signs)
Shade
4'-0"
Batter 2" in 6"
Top of Roadway
8"
8"

FIG. 7



CENTER OF ROAD INSTALLATION SIDE OF ROAD INSTALLATION

FIG. 8

COMMITTEE X

SIGNALS AND INTERLOCKING

Explanatory Note.—The recommendations heretofore appearing under "Signals and Interlocking," have been withdrawn and the references in the following pages substituted. These references include material appearing in the Manual of the Signal Section, American Railway Association.

It consists of:

Definitions.
Signal Symbols.
Signs or Markers for Conveying Instructions to Enginemen and Recommendations.
Train Order Signals.
Table of Interlocking Units and Values.
Signaling Practice.
Switch Indicators.
Specifications.
Plans and Designs.
Miscellaneous.
Instructions, etc.

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COMMITTEE XI

RECORDS AND ACCOUNTS

[1]DEFINITIONS

ACCOUNT.—A statement required to enable payment to be made for labor performed, material furnished, or to establish the detail and total cost of work or class of expenses.

CONVENTIONAL SIGN.—A symbol, such as a mark, character, abbreviation or letter, selected or sanctioned by general agreement or common use to indicate upon map or plan certain forms, conditions or objects, both natural and structural.

COST-KEEPING.—The recording of the expenditures made in doing work for the purpose of having knowledge of the progressive cost of the project, if desired, and of the total cost when completed, and in such units as may be established. Fundamentals for this purpose require that there be an accurate record of all the units of material and their costs, with all the costs for applying such material, with proper credits, if any, for material salvaged.

LEDGER ACCOUNT.—An account of an individual piece of work or class of expense kept in ledger form.

PROGRESS PROFILE.—A graphical record showing status of work at stated periods.

RECORD.—Authenticated information or data in graphical, tabular or statement form relating to physical characteristics, conditions, cost and such other information as may seem desirable for preservation.

REPORT.—The medium through which information is transmitted and from which records and accounts are prepared or compiled.

RIGHT-OF-WAY MAP.—A plat representing the actual location and dimensions of the property, franchises or other rights owned or controlled by a railway company.

STATISTICAL RECORDS.—Authenticated information or data in graphical, tabular or statement form relating to physical characteristics, conditions, cost and such other information as may seem desirable for preservation, systematically gathered.

TRACK CHART.—A diagram showing the physical characteristics of roadway and track.

TRACK MAP.—A plat showing existing physical plant, including tracks, bridges, buildings, water service and mains, leases, station facilities and all other physical and operating property.

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[1] Adopted, Vol. 7, 1906, pp. 279, 318; Vol. 9, 1908, pp. 663, 664, 667, 668, 677, 686; Vol. 18, 1907, pp. 752, 1525; Vol. 22, 1921, pp. 904, 1083; Vol. 26, 1925, pp. 777, 1429.

[2]ENGINEERING DEPARTMENT FORMS

Properly organized and equipped Railway Engineering Departments must have at hand correct information of the progress of work under construction, and the location, extent and condition of the operated property. As means for keeping up this record the following forms are considered essential and recommended (listed in the order in which they are originated):

(A) DESIGN AND CONSTRUCTION DEPARTMENT

Position Originating Form	*Title of Form*	*Form No.*	
Foremen	Time Roll	1119	See Records and Accounts
Construction Inspector	Pile Record Form	701	See Wooden Bridges and Trestles
Materials Inspector	Report of Chemical and Physical Examination of Rails	401-A	See Rail
	Certificate of Inspection	401-B	See Rail
	Report of Shipment		
	Report of Shipment	401-C	See Rail
Resident Engineer	Daily Tracklaying Report and Record	1100	See Records and Accounts
	Daily Ballasting Report and Record	1101	See Records and Accounts
	Resident Engineers' Monthly Estimate of Grading	1102	See Records and Accounts
	Resident Engineers' Monthly Estimate of Bridges and Other Roadway Items	1103	See Records and Accounts
	Resident Engineers' Monthly Estimate of Buildings	1104	See Records and Accounts
	Progress Profile	1122	See Records and Accounts
	Steam Shovel Reports		See Vol. 18, Pro. A.R.E.A., p. 626.
Electrical Engineer	Form of Agreement for Purchase of Electrical Energy		See General Contract Forms
Signal Engineer	Conventional Signs for Signals and Interlocking		See Signal Section Manual
Assistant Engineer or Engineer of Construction	Assistant Engineers' Consolidated Monthly Estimate	1105	See Records and Accounts

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[2] Adopted, Vol. 5, 1904, pp. 237, 372, 375; Vol. 6, 1905, pp. 656, 657, 668; Vol. 11, 1910, pp. 1100, 1103, 1141; Vol. 15, 1914, pp. 924, 1157; Vol. 16, 1915, pp. 786, 1085; Vol. 21, 1920, pp. 368, 1456; Vol. 22, 1921, pp. 902, 1083; Vol. 23, 1922, pp. 433, 1108; Vol. 24, 1923, pp. 799, 1199; Vol. 25, 1924, pp. 677, 1352; Vol. 30, 1929, pp. 650, 1467.

Position Originating Form	*Title of Form*	*Form No.*	
Any Officer in Charge of Work	Authority for Expenditure	1113	See Records and Accounts
	Detailed Estimate	1114	See Records and Accounts
Chief Engineer	Form of Proposal		See General Contract Forms
	Form of Construction Contract		See General Contract Forms
	Form of Bond		See General Contract Forms
	Conventional Signs, Maps and Profiles		See Records and Accounts
	Specifications for Maps and Profiles		See Records and Accounts
	Form of Option for Purchase of Land		See General Contract Forms

(B) MAINTENANCE DEPARTMENT

All Foremen	Time Roll	1119	See Records and Accounts
Track Foremen	Report of Rail Failure in Main Track	402-A	See Rail
	Monthly Track Material Report	1107	See Records and Accounts
	Report of Order Work		See Economics of Railway Labor
	Daily Record Track Work Performance	1107-A	See Economics of Railway Labor
	Motor Car Operator's and Maintainer's Monthly Report		See Economics of Railway Labor
Bridge Foremen	Monthly Bridge Material Report	1108	See Records and Accounts
	Bridge Section Tool Report	1109	See Records and Accounts
Painter Foreman	Building Painting Report	600	See Buildings
Steam Shovel and Ditcher Foreman	Steam Shovel Reports		See Vol. 18, Pro. A.R.E.A., p. 626
Pumper	Pumper's Daily Report	1301	See Water Service
Division Bridge Inspector	Current Bridge Inspection Report	1111	See Records and Accounts
Motor Car Inspector	Motor Car Condition Report		See Economics of Railway Labor
General Bridge Inspector	Bridge Inspection Report	1110	See Records and Accounts
Signal Maintainer	Signal Maintainer's Report (See Form RSA 21)		See Signal Section Manual
	Signal Inspector's or Maintainer's Report (See Form RSA 22)		See Signal Section Manual

Position Originating Form	*Title of Form*	*Form No.*	
Signal Supervisor	Trainmen's Telegraphic Report (See Form RSA 11)		See Signal Section Manual
	Dispatcher's Telegraphic Report (See Form RSA 12)		See Signal Section Manual
	Signal Engineer's or Supervisor's Report (See Form RSA 3)		See Signal Section Manual
Division Engineer	Rail Failures for Month on Division	402-B	See Rail
	Statement of Rails in Main Track—Division	402-D	See Rail
	Statement of Cost of Pumping Water	1302	See Water Service
	Water Station Record	1303	See Water Service
	Record of Deep Wells	1304	See Water Service
	Section Planning Sheet		See Economics of Railway Labor
Supervisor of Wood Preserving Plant	Form A—Report of Inspection of Treatment	1700	See Wood Preservation
	Form B—Report of Inspection of Treatment	1701	See Wood Preservation
Supervisor of Work Equipment and Roadway Machines	Recapitulation of Roadway Motor Car Report		See Economics of Railway Labor
	Roadway Motor Car Service and Maintenance		See Economics of Railway Labor
Any Officer in Charge of Work	Authority for Expenditure.	1113	See Records and Accounts
	Detailed Estimate	1114	See Records and Accounts
Chief Engineer of Maintenance	Contract and Lease Record	1120	See Records and Accounts
	Track Chart	1121	See Records and Accounts
	Rail Failures for Year	402-C	See Rail
	Statement of Transverse Fissure Rail Failures	402-E	See Rail
	Location Diagram of Rails Removed	403-A	See Rail
	Diagram Showing Lines of Wear	403-B	See Rail
	Statement of Comparative Wear of Test Rail	403-C	See Rail
	Side Track Record	1106	See Records and Accounts
	Register of Title Deeds (See DV Forms 107-8 ICC)		

Position Originating Form	*Title of Form*	*Form No.*	
Chief Engineer Maintenance	Form of Agreement for Trackage Rights		See General Contract Forms
	Form of License for Wires, Pipes, Conduits, Drains, Hopper Pits and Other Structures on Railway Property		See General Contract Forms
	Form of Agreement for Placing Snow or Sand Fences Beyond the Railway Company's Property Line		See General Contract Forms
	Form of Agreement for Joint Use of Passenger Station Facilities		See General Contract Forms
	Form of Agreement for Joint Use of Poles on Railway Rights of Way		See General Contract Forms
	Form of Agreement for Furnishing Water from Railway Water Systems to Employees and Others		See General Contract Forms
Supervisor Valuation Order No. 3			

(C) VALUATION DEPARTMENT

Supervisor Valuation Order No. 3	Register of Authorities for Expenditure	1115	See Records and Accounts
	Roadway Completion Report	1117 1117-C	See Records and Accounts
	Equipment Completion Report	1118	See Records and Accounts
Supervisor R&E Accounting Branch	Monthly Report of Expenditures	1116	See Records and Accounts
Auditor of Capital Expenditures	Authority for Expenditure	1113	See Records and Accounts
	Detailed Estimate	1114	See Records and Accounts

[3]FORMS FOR SPECIAL STUDIES

1. Cost-Keeping Methods, Statistical Records, and Forms for analyzing expenditures for assistance in controlling expenditures are shown on pages 758-788.

2. Forms for Time Studies of Ballasting, Rail Renewals, Cross-Tie Renewals, Raising Track, and Instructions for Reporting and Distributing Track Work Time Charges are shown on pages 1449-1466.

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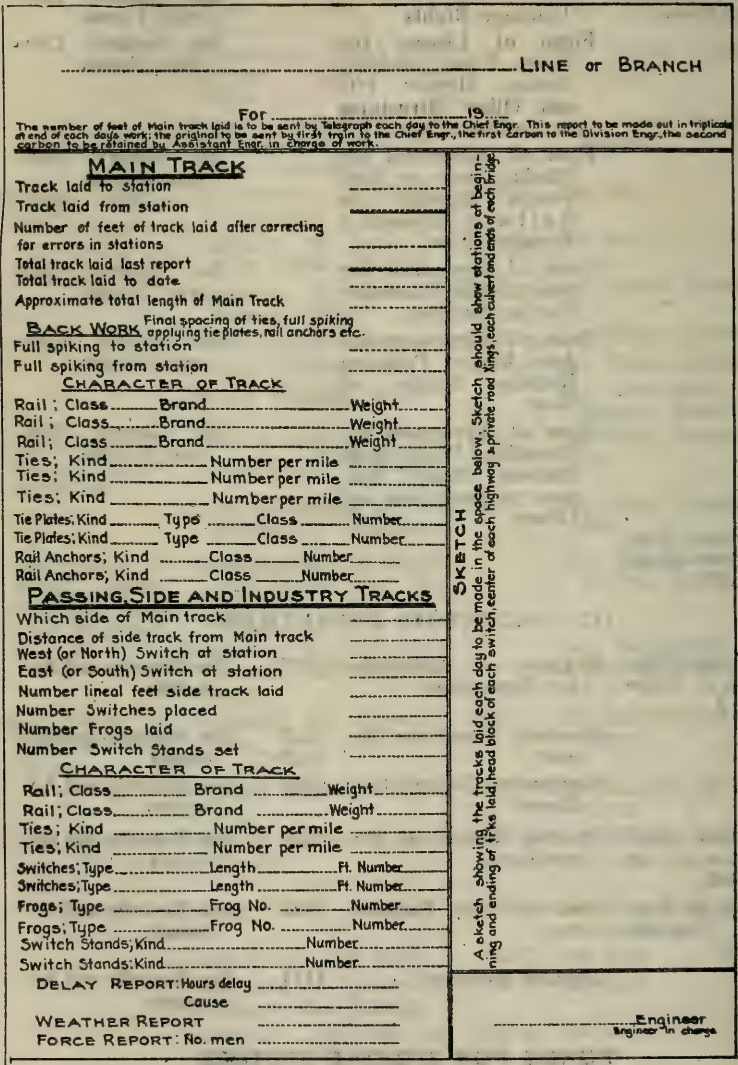
[3] **Adopted, Vol. 23, 1922, pp. 687, 1033; Vol. 26, 1925, pp. 776, 1428.**

DAILY TRACKLAYING REPORT AND RECORD

Size 8½x11 inches. Form 1100



....LINE or BRANCH

For .... 19....

The number of feet of Main track laid is to be sent by Telegraph each day to the Chief Engr. This report to be made out in triplicate at end of each days work; the original to be sent by first train to the Chief Engr., the first carbon to the Division Engr., the second carbon to be retained by Assistant Engr. in charge of work.

MAIN TRACK

Track laid to station ....

Track laid from station ....

Number of feet of track laid after correcting for errors in stations ....

Total track laid last report ....

Total track laid to date ....

Approximate total length of Main Track ....

BACK WORK Final spacing of ties, full spiking applying tie plates, rail anchors etc.

Full spiking to station ....

Full spiking from station ....

CHARACTER OF TRACK

Rail; Class ...... Brand ...... Weight ......

Rail; Class ...... Brand ...... Weight ......

Rail; Class ...... Brand ...... Weight ......

Ties; Kind ...... Number per mile ......

Ties; Kind ...... Number per mile ......

Ties; Kind ...... Number per mile ......

Tie Plates; Kind ...... Type ...... Class ...... Number ......

Tie Plates; Kind ...... Type ...... Class ...... Number ......

Rail Anchors; Kind ...... Class ...... Number ......

Rail Anchors; Kind ...... Class ...... Number ......

PASSING, SIDE AND INDUSTRY TRACKS

Which side of Main track ....

Distance of side track from Main track ....

West (or North) Switch at station ....

East (or South) Switch at station ....

Number lineal feet side track laid ....

Number Switches placed ....

Number Frogs laid ....

Number Switch Stands set ....

CHARACTER OF TRACK

Rail; Class ...... Brand ...... Weight ......

Rail; Class ...... Brand ...... Weight ......

Ties; Kind ...... Number per mile ......

Ties; Kind ...... Number per mile ......

Switches; Type ...... Length ...... Ft. Number ......

Switches; Type ...... Length ...... Ft. Number ......

Frogs; Type ...... Frog No. ...... Number ......

Frogs; Type ...... Frog No. ...... Number ......

Switch Stands; Kind ...... Number ......

Switch Stands; Kind ...... Number ......

DELAY REPORT: Hours delay ....

Cause ....

WEATHER REPORT ....

FORCE REPORT: No. men ....

SKETCH

A sketch showing the tracks laid each day to be made in the space below. Sketch should show stations of beginning and ending of tracks laid, head block of each switch, center of each highway & private road xings, each culvert and ends of each bridge.

.... Engineer
Engineer in charge

SPECIFICATIONS FOR FORM 1100.

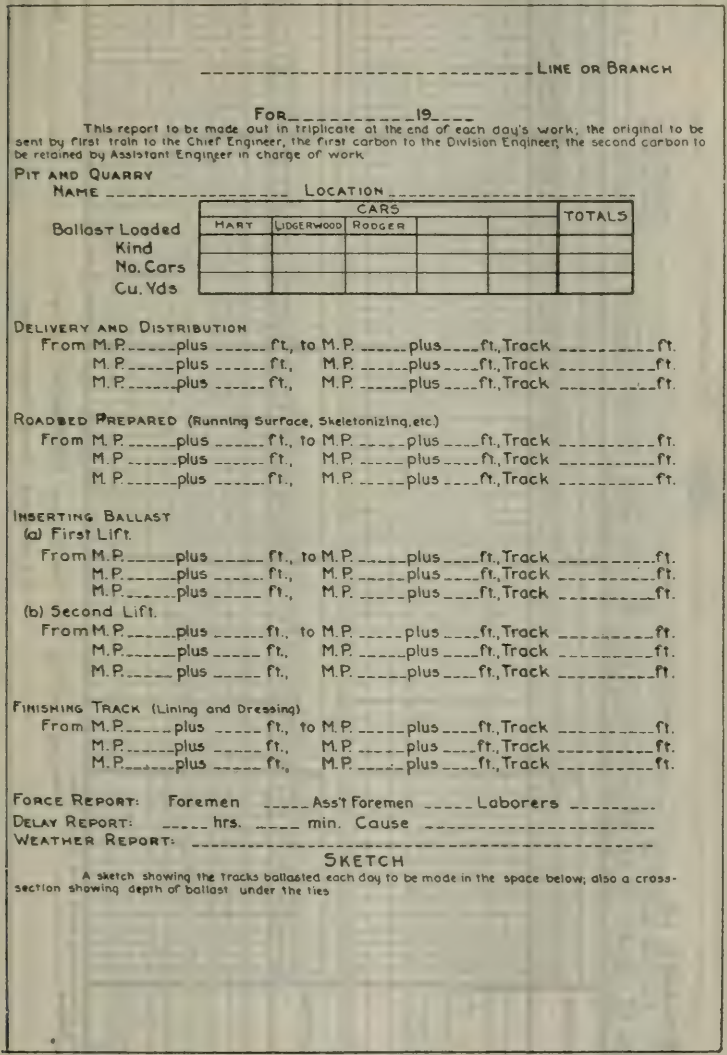
Form as shown. Size 8½x11 inches. All lines and printing black. Perforated for binding in loose-leaf binder for permanent record after serving as report.

INSTRUCTIONS FOR USE OF FORM 1100.

Instructions for the use of the form are given under the title of the form.

DAILY BALLASTING REPORT AND RECORD

Size 8½x11 inches **Form 1101**



------------------------------ LINE OR BRANCH

FOR ---------- 19----

This report to be made out in triplicate at the end of each day's work; the original to be sent by first train to the Chief Engineer, the first carbon to the Division Engineer, the second carbon to be retained by Assistant Engineer in charge of work.

PIT AND QUARRY
NAME ------------------ LOCATION ----------------------

Ballast Loaded	CARS					TOTALS
	HART	LIDGERWOOD	RODGER			
Kind						
No. Cars						
Cu. Yds						

DELIVERY AND DISTRIBUTION
From M.P. ----- plus ------ ft., to M.P. ------ plus ---- ft., Track ---------- ft.
M.P. ----- plus ------ ft., M.P. ------ plus ---- ft., Track ---------- ft.
M.P. ----- plus ------ ft., M.P. ------ plus ---- ft., Track ---------- ft.

ROADBED PREPARED (Running Surface, Skeletonizing, etc.)
From M.P. ------ plus ------ ft., to M.P. ----- plus ---- ft., Track ---------- ft.
M.P. ------ plus ------ ft., M.P. ----- plus ---- ft., Track ---------- ft.
M.P. ------ plus ------ ft., M.P. ----- plus ---- ft., Track ---------- ft.

INSERTING BALLAST
(a) First Lift.
From M.P. ----- plus ----- ft., to M.P. ----- plus ---- ft., Track ---------- ft.
M.P. ------ plus ----- ft., M.P. ----- plus ---- ft., Track ---------- ft.
M.P. ------ plus ----- ft., M.P. ----- plus ---- ft., Track ---------- ft.
(b) Second Lift.
From M.P. ------ plus ------ ft., to M.P. ----- plus ---- ft., Track ---------- ft.
M.P. ------ plus ----- ft., M.P. ----- plus ---- ft., Track ---------- ft.
M.P. ----- plus ----- ft., M.P. ----- plus ---- ft., Track ---------- ft.

FINISHING TRACK (Lining and Dressing)
From M.P. ----- plus ----- ft., to M.P. ----- plus ---- ft., Track ---------- ft.
M.P. ------ plus ----- ft., M.P. ----- plus ---- ft., Track ---------- ft.
M.P. ------ plus ----- ft., M.P. ----- plus ---- ft., Track ---------- ft.

FORCE REPORT: Foremen ----- Ass't Foremen ----- Laborers ---------
DELAY REPORT: ----- hrs. ---- min. Cause -----------------------
WEATHER REPORT: ---

SKETCH

A sketch showing the tracks ballasted each day to be made in the space below; also a cross-section showing depth of ballast under the ties

SPECIFICATIONS FOR FORM 1101.

Form as shown. Size 8½x11 inches. All lines and printing black. Perforated for binding in loose-leaf binder for permanent record after serving as report.

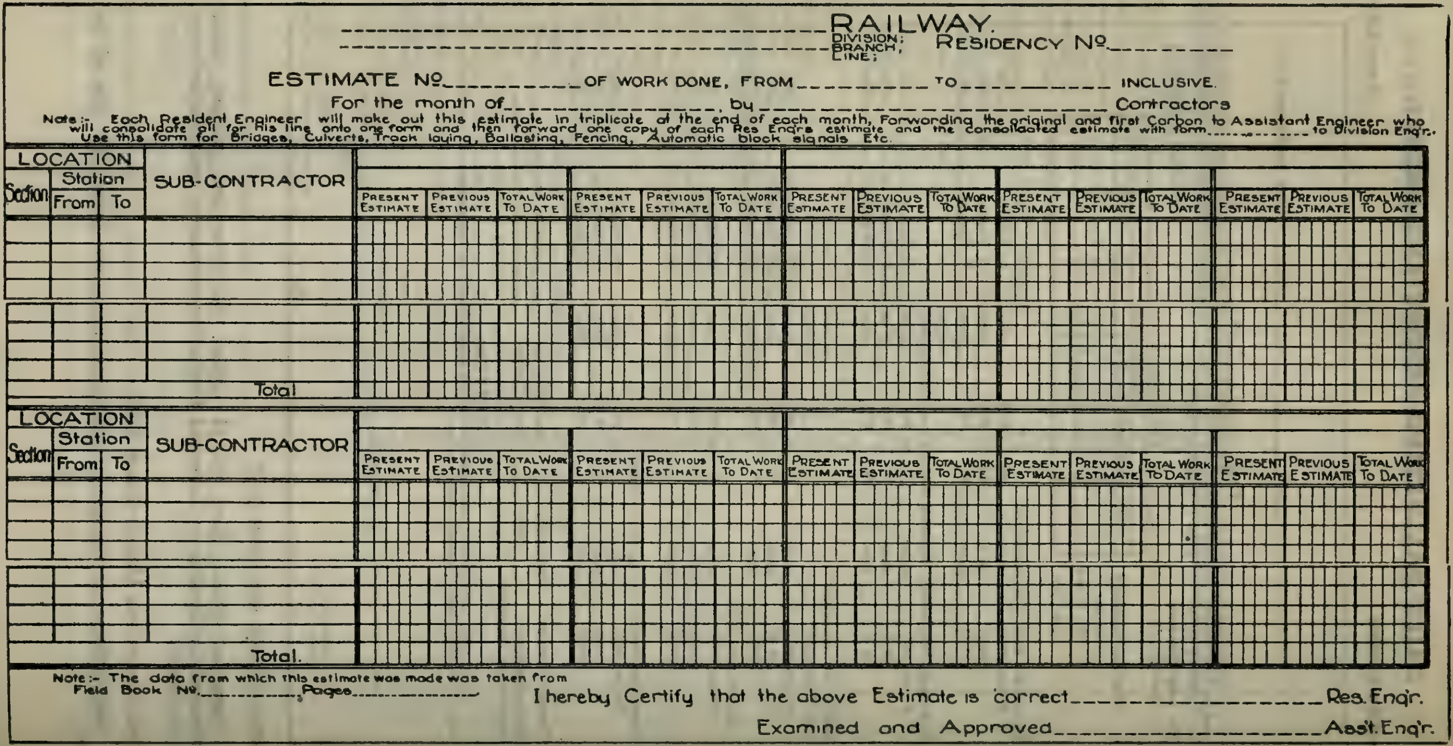
INSTRUCTIONS FOR USE OF FORM 1101.

Instructions for the use of this form are given under the title of the form.

RESIDENT ENGINEER'S MONTHLY ESTIMATE OF GRADING

Form 1102

Size 11x17 inches



---------------------------------------RAILWAY.
---------------------------------------DIVISION; BRANCH; LINE; RESIDENCY Nº---------

ESTIMATE Nº---------OF WORK DONE, FROM---------TO----------INCLUSIVE.

For the month of--------------, by ----------------------- Contractors

Note:- Each Resident Engineer will make out this estimate in triplicate at the end of each month, Forwarding the original and first Carbon to Assistant Engineer who will consolidate all for his line onto one form and then forward one copy of each Res Engrs estimate and the consolidated estimate with form------------to Division Engr. Use this form for Bridges, Culverts, Track laying, Ballasting, Fencing, Automatic block signals Etc.

LOCATION			SUB-CONTRACTOR															
Section	Station																	
	From	To		Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date
			Total															

LOCATION			SUB-CONTRACTOR															
Section	Station																	
	From	To		Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date
			Total.															

Note:- The data from which this estimate was made was taken from Field Book Nº.-----------, Pages.----------------

I hereby Certify that the above Estimate is correct-----------------Res. Engr.

Examined and Approved-----------------Asst. Engr.

RESIDENT ENGINEER'S MONTHLY ESTIMATE OF BRIDGES AND OTHER ROADWAY ITEMS

Form 1103

Size 11x17 inches

______________________ RAILWAY

______________________ Division / Branch / Line Residency No.__________

Estimate No.____________ Of Work Done, From________________ To________________ Inclusive.

For the month of________________________, by________________________ Contractors

Note: Each Resident Engineer will make out this estimate in triplicate at the end of each month, forwarding the original and first carbon to Assistant Engineer, who will consolidate all for his line onto one form, and then forward one copy of each Resident Engineer's estimate and the consolidated estimate with Form_____ to Division Engineer

LOCATION			SUB-CONTRACTOR	CLEARING AND GRUBBING						EXCAVATION								
Section	Station			Clearing - Acres			Grubbing - Sta. of 100 Ft.			Earth - Cubic Yards			Loose Rock - Cubic Yards			Solid Rock - Cubic Yards		
	From	To		Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date
			TOTALS															

LOCATION			SUB-CONTRACTOR							EXTRA HAUL								
Section	Station									Over Haul - Cu. Yds. per 100 Ft.			Train Haul - Cu. Yds. per Mile					
	From	To		Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date	Present Estimate	Previous Estimate	Total Work To Date
			TOTALS															

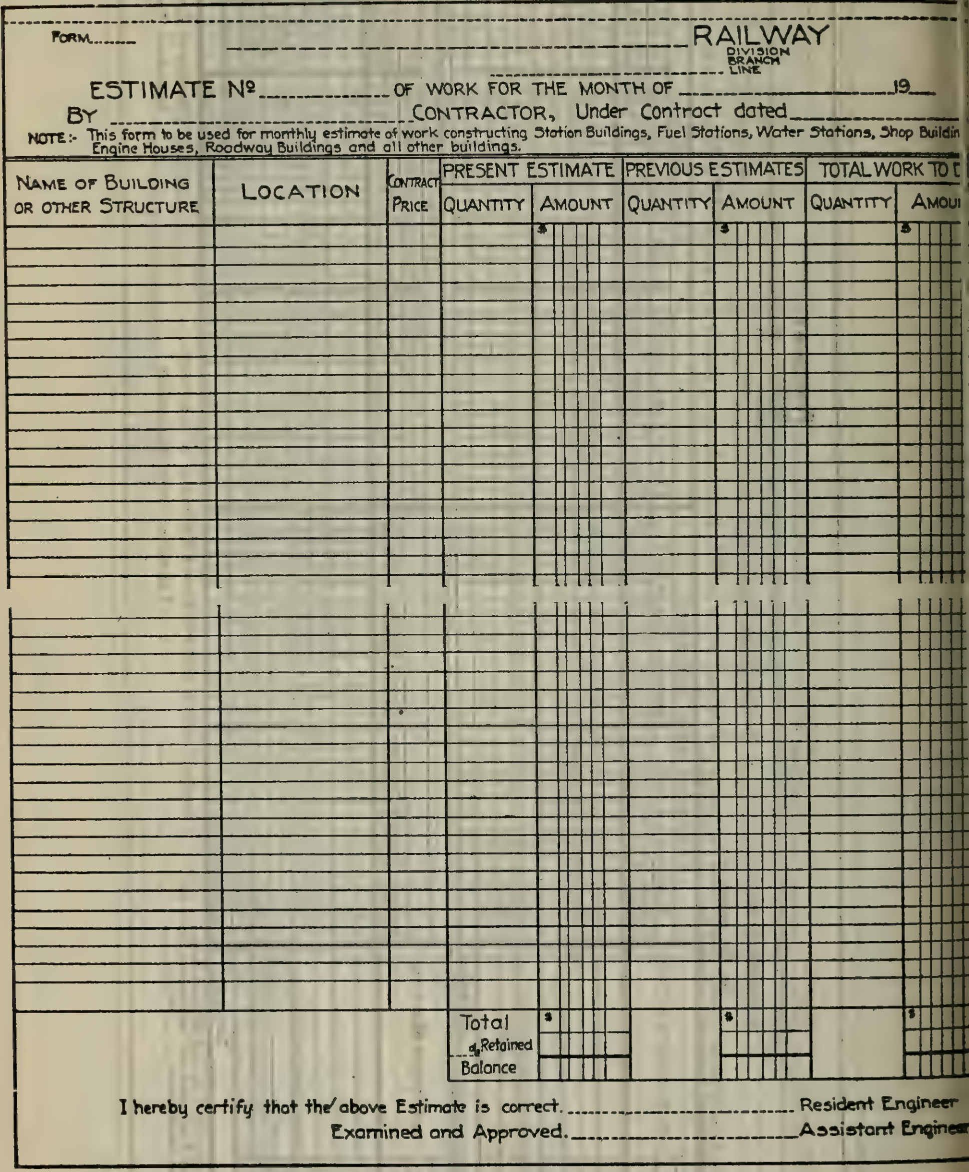
Note: Blank columns to be used for other items.
Note: The data from which this estimate was made was taken from Field Note Book No._______ Pages_____

I hereby Certify that the above Estimate is Correct____________________ Resident Engineer.

Examined and Approved____________________ Assistant Engineer.

RESIDENT ENGINEER'S MONTHLY ESTIMATE OF BUILDINGS

Size 11x17 inches Forr



FORM.......

________________________________ RAILWAY
DIVISION
BRANCH
LINE

ESTIMATE Nº.............. OF WORK FOR THE MONTH OF .... 19....

BY .... CONTRACTOR, Under Contract dated..............

NOTE:- This form to be used for monthly estimate of work constructing Station Buildings, Fuel Stations, Water Stations, Shop Buildin Engine Houses, Roadway Buildings and all other buildings.

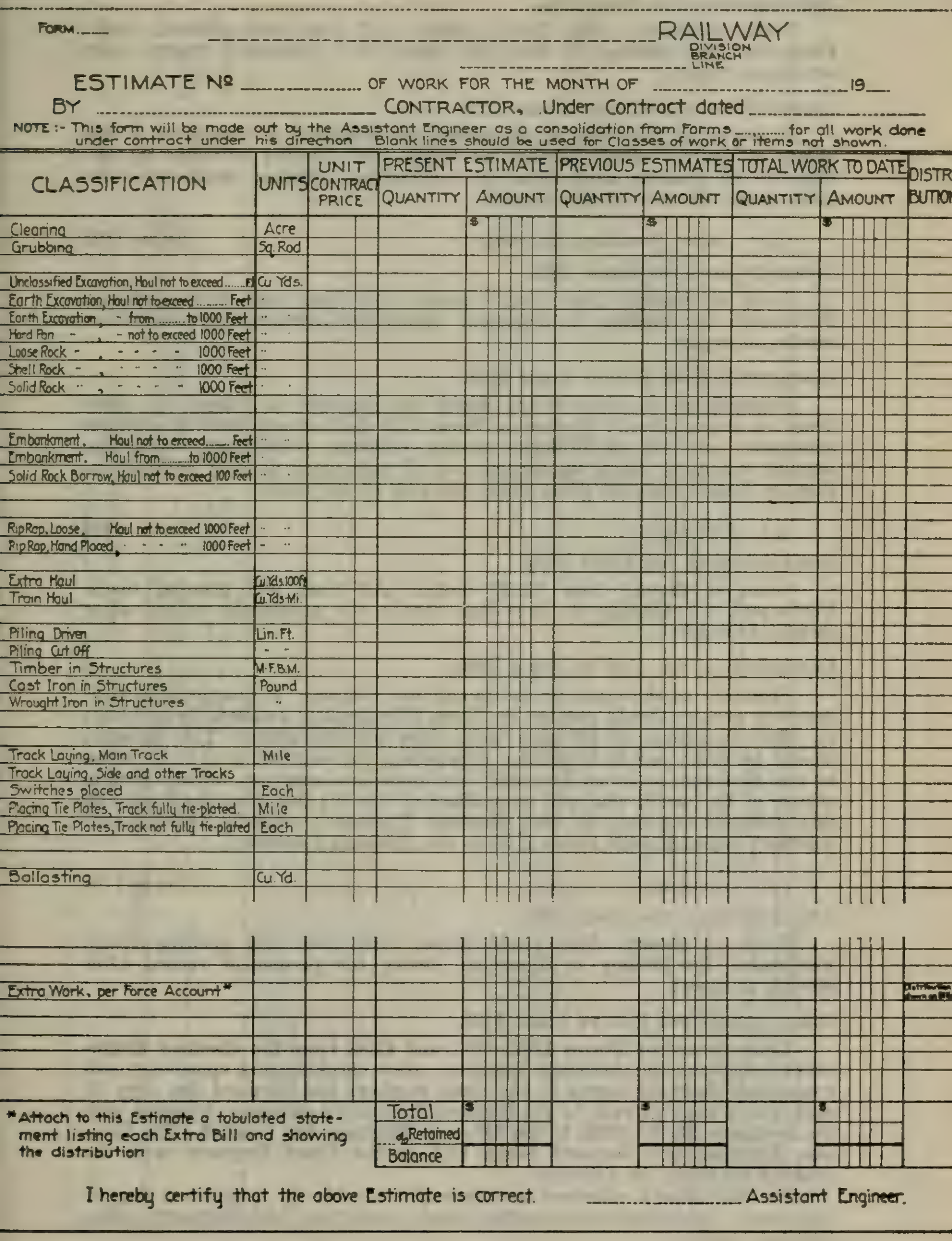
NAME OF BUILDING OR OTHER STRUCTURE	LOCATION	CONTRACT PRICE	PRESENT ESTIMATE		PREVIOUS ESTIMATES		TOTAL WORK TO	
			QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOU
				$		$		$
			Total	$		$		$
			___% Retained					
			Balance					

I hereby certify that the above Estimate is correct. .... Resident Engineer

Examined and Approved. .... Assistant Enginee

ASSISTANT ENGINEER'S CONSOLIDATED MONTHLY ESTIMATE

Size 11x17 inches Form 110



FORM.____

______________________________________RAILWAY DIVISION BRANCH LINE

ESTIMATE Nº ____________ OF WORK FOR THE MONTH OF ____________________ 19__

BY ______________________________ CONTRACTOR, Under Contract dated ____________________

NOTE :- This form will be made out by the Assistant Engineer as a consolidation from Forms .... for all work done under contract under his direction Blank lines should be used for Classes of work or items not shown.

CLASSIFICATION	UNITS	UNIT CONTRACT PRICE	PRESENT ESTIMATE		PREVIOUS ESTIMATES		TOTAL WORK TO DATE		DISTR BUTIO
			QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	
Clearing	Acre			$		$		$	
Grubbing	Sq. Rod								
Unclassified Excavation, Haul not to exceed ....Ft	Cu Yds.								
Earth Excavation, Haul not to exceed .... Feet	"								
Earth Excavation, " from .... to 1000 Feet	" "								
Hard Pan " , " not to exceed 1000 Feet	" "								
Loose Rock " , " " " " 1000 Feet	"								
Shell Rock " , " " " " 1000 Feet	"								
Solid Rock " , " " " " 1000 Feet	" "								
Embankment. Haul not to exceed....... Feet	" "								
Embankment. Haul from .... to 1000 Feet	"								
Solid Rock Borrow, Haul not to exceed 100 Feet	" "								
RipRap, Loose, Haul not to exceed 1000 Feet	" "								
RipRap, Hand Placed, " " " 1000 Feet	" "								
Extra Haul	Cu.Yds.100ft								
Train Haul	Cu.Yds-Mi.								
Piling Driven	Lin. Ft.								
Piling Cut Off	" "								
Timber in Structures	M.F.B.M.								
Cast Iron in Structures	Pound								
Wrought Iron in Structures	"								
Track Laying, Main Track	Mile								
Track Laying, Side and other Tracks									
Switches placed	Each								
Placing Tie Plates, Track fully tie-plated.	Mile								
Placing Tie Plates, Track not fully tie-plated	Each								
Ballasting	Cu. Yd.								
Extra Work, per Force Account*									
			Total	$		$		$	
			% Retained						
			Balance						

*Attach to this Estimate a tabulated statement listing each Extra Bill and showing the distribution

I hereby certify that the above Estimate is correct. ________________ Assistant Engineer.

MONTHLY AND FINAL ESTIMATES OF CONTRACT WORK:

(a) *Grading* Form 1102

SPECIFICATIONS FOR FORM 1102.

Form as shown. Size 11x17 inches. All lines and printing black. Perforated for binding in loose-leaf binder for permanent record after serving as report.

INSTRUCTIONS FOR USE OF FORM 1102.

Promptly at the close of the month the Engineer in charge of a residency or project should prepare on Form 1102 detailed estimates by stations of all grading work done by contractors. Further instructions are given under the title of the form.

(b) *Other Roadway Accounts* Form 1103

SPECIFICATIONS FOR FORM 1103.

Form as shown. Size 11x17 inches. All lines and printing black. Perforated for binding in loose-leaf binder for permanent record after serving as report.

INSTRUCTIONS FOR USE OF FORM 1103.

Promptly at the close of the month the Engineer in charge of a residency or project should prepare on Form 1103 detailed estimates by stations, structures, etc., of all bridges, trestles, culverts, tracklaying, ballasting, fencing, automatic block signals, etc., of all such work done by contractors. Further instructions are given under the title of the form.

(c) *Buildings* Form 1104

SPECIFICATIONS FOR FORM 1104.

Form as shown. Size 11x17 inches. All lines and printing black. Perforated for binding in loose-leaf binder for permanent record after serving as report.

INSTRUCTIONS FOR USE OF FORM 1104.

Promptly at the close of the month the Engineer in charge of a residency or project should prepare on Form 1104 detailed estimate by buildings or other structures of all such work done by contractors. This estimate should be made out in triplicate, forwarding the original and first carbon to the Assistant or other Engineer, his immediate superior, having general charge of the work, who will consolidate all for his line onto one form and then forward one copy of each Resident Engineer's estimate and the consolidated estimate with Form 1105 to the Division Engineer.

(d) *Summary* Form 1105

SPECIFICATIONS FOR FORM 1105.

Form as shown. Size 11x17 inches. All lines and printing black. Perforated for binding in loose-leaf binder for permanent record after serving as report.

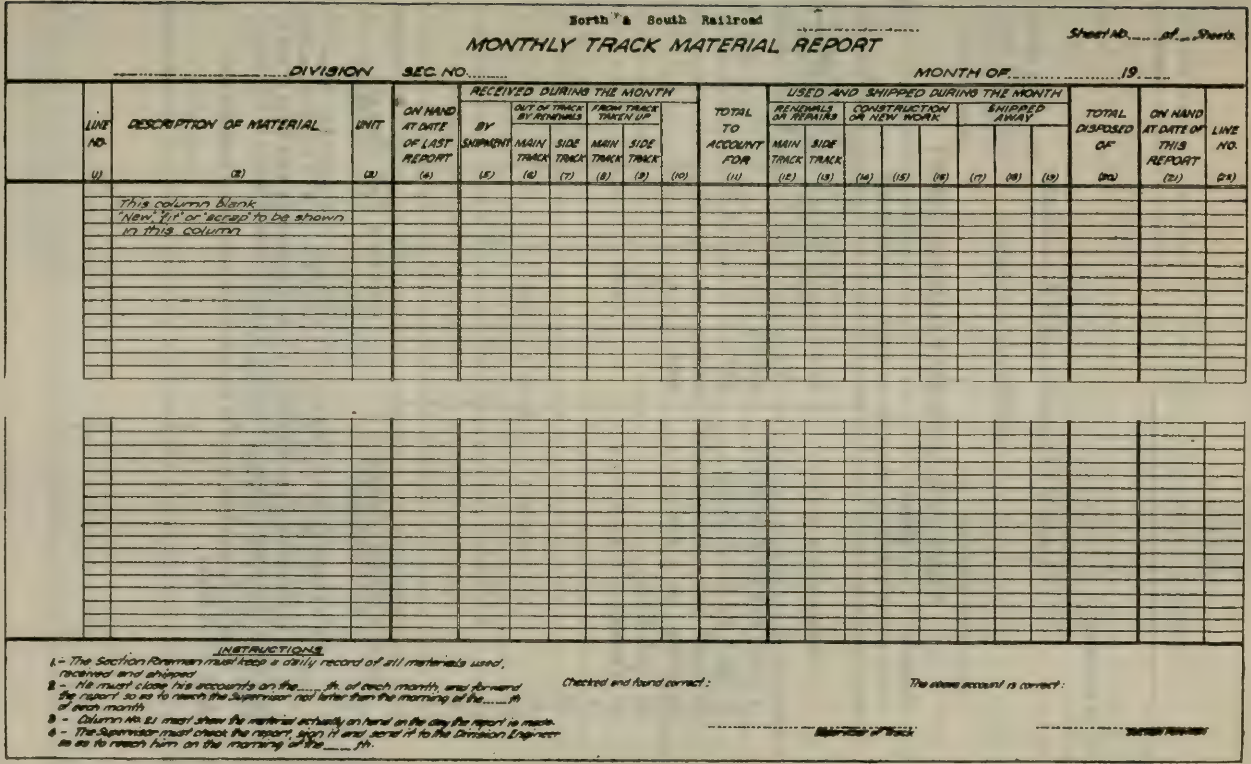
INSTRUCTIONS FOR USE OF FORM 1105.

Upon receipt of Forms 1102, 1103, and 1104, from the Resident Enginneers under him the Assistant Engineer, after checking and approving, will consolidate them on forms of the same numbers and forward one copy of each with a copy of each of the Resident Engineer's estimates, together with the summary M. W. 1105, to the Division Engineer for voucher. The Division Engineer will forward Form 1105 to the Chief Engineer with the voucher covering the estimate.

As contractor's estimates are generally payable on a specified day of the month, the estimate and voucher should reach the Chief Engineer's office ten days earlier.

MONTHLY TRACK MATERIAL REPORT

Form 1107



North & South Railroad

MONTHLY TRACK MATERIAL REPORT

Sheet No.......of...Sheets

.............................DIVISION SEC. NO.........

MONTH OF.........................19.....

					RECEIVED DURING THE MONTH							USED AND SHIPPED DURING THE MONTH									
						OUT OF TRACK BY RENEWALS		FROM TRACK TAKEN UP				RENEWALS OR REPAIRS		CONSTRUCTION OR NEW WORK			SHIPPED AWAY				
	LINE NO.	DESCRIPTION OF MATERIAL	UNIT	ON HAND AT DATE OF LAST REPORT	BY SHIPMENT	MAIN TRACK	SIDE TRACK	MAIN TRACK	SIDE TRACK		TOTAL TO ACCOUNT FOR	MAIN TRACK	SIDE TRACK						TOTAL DISPOSED OF	ON HAND AT DATE OF THIS REPORT	LINE NO.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
		This column blank																				
		"New," "fit" or "scrap" to be shown																				
		in this column																				

INSTRUCTIONS

1.– The Section Foreman must keep a daily record of all materials used, received and shipped

2 – He must close his accounts on the.....th. of each month, and forward the report so as to reach the Supervisor not later than the morning of the.....th of each month

3 – Column No. 21 must show the material actually on hand on the day the report is made.

4 – The Supervisor must check the report, sign it and send it to the Division Engineer so as to reach him on the morning of the.....th.

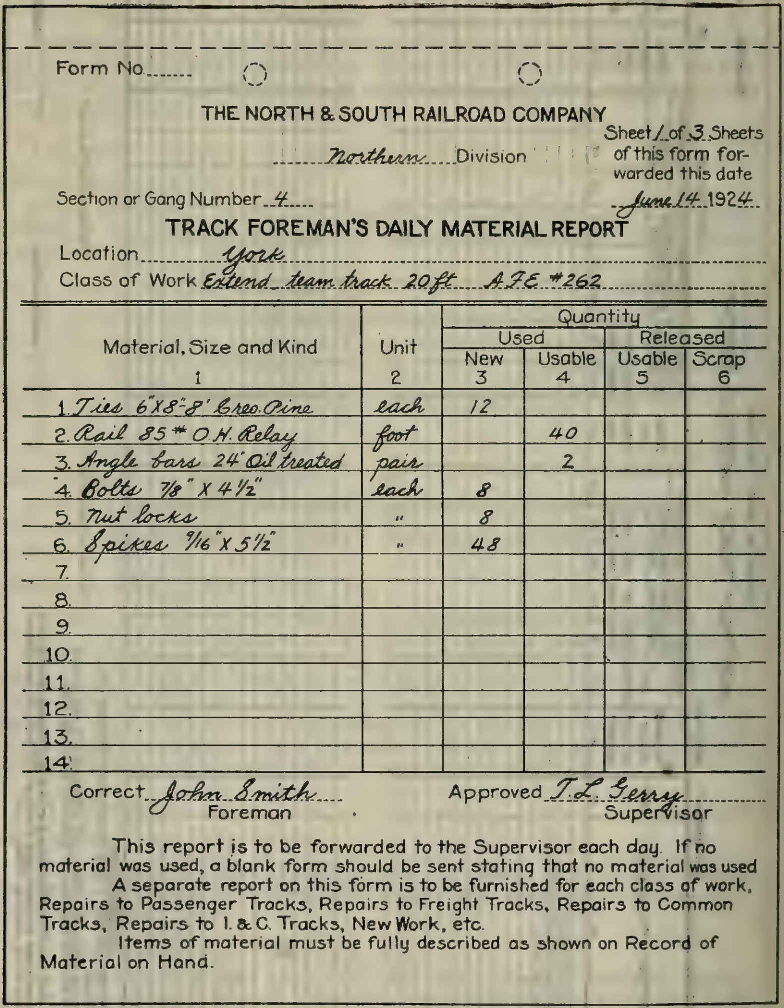
Checked and found correct:

..............................Supervisor of Track

The above account is correct:

..............................Section Foreman

Form 1107-A



Form No.......

THE NORTH & SOUTH RAILROAD COMPANY

Northern Division

Sheet 1 of 3 Sheets of this form forwarded this date

June 14 1924

Section or Gang Number 4

TRACK FOREMAN'S DAILY MATERIAL REPORT

Location York

Class of Work Extend team track 20 ft A.F.E. #262

Material, Size and Kind 1	Unit 2	Quantity Used New 3	Quantity Used Usable 4	Quantity Released Usable 5	Quantity Released Scrap 6
1. Ties 6"x8"-8' Creo. Pine	each	12			
2. Rail 85# O.H. Relay	foot		40		
3. Angle bars 24" Oil treated	pair		2		
4. Bolts 7/8" x 4½"	each	8			
5. Nut locks	"	8			
6. Spikes 9/16" x 5½"	"	48			
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					

Correct John Smith
Foreman

Approved T. L. Gerry
Supervisor

This report is to be forwarded to the Supervisor each day. If no material was used, a blank form should be sent stating that no material was used.

A separate report on this form is to be furnished for each class of work, Repairs to Passenger Tracks, Repairs to Freight Tracks, Repairs to Common Tracks, Repairs to I. & C. Tracks, New Work, etc.

Items of material must be fully described as shown on Record of Material on Hand.

Size 8½x11 inches Form 1108

North and South Railroad

..........................DIVISION

MONTHLY BRIDGE MATERIAL REPORT

.... Month of..............................19...
(Gang or District.)

KIND OF MATERIAL	UNIT	ON HAND FIRST OF MONTH	RECEIVED	DISPOSED OF		ON HAND END OF MONTH	REMARKS
				USED	SHIPPED AWAY		
← 2.2" →	0.6"	0."7	0."7	0."7	0."7	0."7	← 2.2" →

The above statement is correct:

....
Foreman of Bridges.

Approved:..
Master Carpenter.

Size 8½x11 inches Form 1109

North and South Railroad

BRIDGE SECTION TOOL REPORT

....
(Gang or District.)

..........................Division. For..................ending...................19...

TOOLS	ON HAND ____1ST	RECEIVED	SENT TO SHOP FOR REPAIRS	BROKEN OR WORN OUT	ON HAND	TOOLS	ON HAND ____1ST	RECEIVED	SENT TO SHOP FOR REPAIRS	BROKEN OR WORN OUT	ON HAND
← 2" →	0."5	0."5	0."5	0."5	0."5	← 1."5 →	0."5	0."5	0."5	0."5	0."5

The above statement is correct:

.... Approved:...
Foreman of Bridges. Master Carpenter.

Form 1110

North and South Railroad

BRIDGE INSPECTION REPORT

_______________ Division For _______________

From _______________ To _______________ Inspected by _______________ 19__

Bridge No. or Structure	Location	Kind of Structure	Bridge Data	Date Inspected	Condition, Description of Work Required, Action Taken, or Recommendations
					(This report to be signed also by those composing inspection party)

Size, 11"x24"

Form 1106

A. B. & C. R. R. Co.—Side Track Record

Side Tracks on ____________ Division ____________ Sub-Division ____________ Valuation Section

	Location										Total, Dec. 31, 19—				Changes During Year				
											Ownership				Ownership				
											Railroad				Railroad				
Mile Post	Right or Left	Station	County and State	Township or School District	Name or Number of Track	Connected or Spur	A F E Number	Contract Number	Date Completed	Character of Rail Length of Service, Weight and Kind	InCorp. Limits	In County	Private	Total	InCorp Limits	In County	Private	Total	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
Amount brought forward.																			
Amount carried forward.																			

1. Track:

(a)	*Side Track Record*	Form 1106
(b)	*Monthly Track Material Report*	Form 1107
(c)	*Track Foreman's Daily Material Report*	Form 1107-A

Specifications for Form 1107.

Form as shown. Size 11x17 inches. Six horizontal lines per inch. All lines and printing black.

Instructions for Use of Form 1107.

Instructions for the use of this form are given at the bottom of the form.

2. Bridges and Buildings:

(a)	*Monthly Bridge Material Report*	Form 1108

Specifications for Form 1108

Form as shown. Size 8½x11 inches. Three horizontal lines per inch. All lines and printing black.

Instructions for Use of Form 1108.

Foremen are required to make the above report...................... and forward same to Master Carpenter, who will, after examining, approve it and forward to Division Engineer.

(b)	*Bridge Section Tool Report*	Form 1109

Specifications for Form 1109.

Form as shown. Size 8½x11 inches. Three horizontal lines per inch. All lines and printing black.

Instructions for Use of Form 1109.

Foremen are required to make the above report...................... and forward same to Master Carpenter, who will, after examining, approve it and forward to Division Engineer.

(c)	*Bridge Inspection Report*	Form 1110

Specifications for Form 1110

Form as shown. Size 11x8½ inches. All lines and printing black.

Instructions for Use of Form 1110.

In Bridge Inspection there should be a clear distinction made between General Inspection and Current Inspection.

The purpose of the General Inspection, frequently called the annual inspection, although in many cases conducted semi-annually or even quarterly, is not only to check the maintenance work of the division organization, but to make a more careful investigation of important bridges and structures on the entire road and further to ascertain and determine what extensive repair work or renewal work should be done in the following working season.

Numerous minor special forms are used on all railways for reporting information necessary to keep bridge records up to date, but such forms should be regulated by each individual railway according to its peculiar requirements.

Bridge records, when properly kept up to date in an accurate manner, will prove of the highest value to railways and have become essential because of recent legislation.

Size 4x6 inches **Form 1111**

Report No.______

North and South Railroad.

__________Division

CURRENT BRIDGE INSPECTION REPORT

I have to-day inspected______________________

at ______________________

and find its condition as follows:

____

____

The following work is required to maintain structure in good condition:

____

____

The following work must be done to keep the structure safe:

____

____

______________________ *Inspector.*

Date,______________19

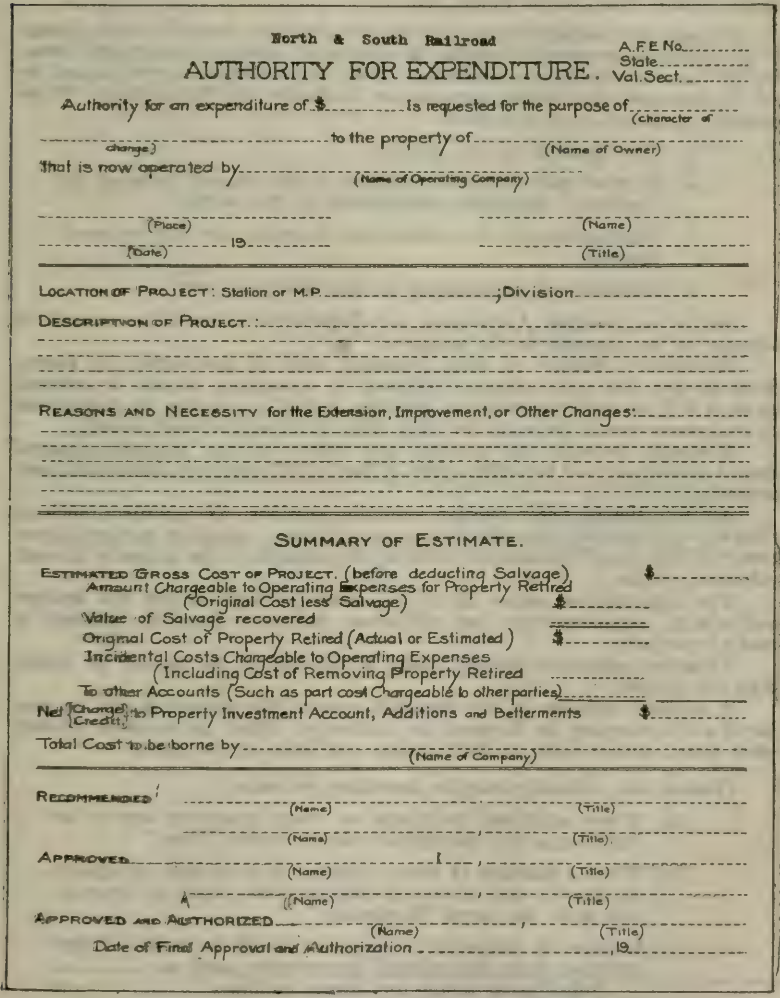
NOTE.—Make separate report for each bridge or structure inspected. Send report to the__________of the Division. Report by telegraph to the__________and the Superintendent of the Division all serious defects that require attention.

(c) *Current Bridge Inspection Report* Form 1111

Form as shown. Size 4x6 inches. Printed on manila cardboard, all lines and printing black, addressed on the reverse side to the proper official.

To be sent as a postal report. The purpose of the Current Inspection, clearly distinguished from the General Inspection, is to keep the structure in safe condition, to discover any defects and to report the same promptly, so that repairs can be made before the safety of the structure is affected. It is important that a simple record should be made while at the bridge and that the superior officer be kept advised of all such inspections, whether made by a Bridge Mechanic, Gang Foreman, Division Bridge Inspector, Master Carpenter or others.

Size 8½x11 inches **Form 1115**



North & South Railroad

AUTHORITY FOR EXPENDITURE.

A.F.E. No. ----------
State ----------
Val. Sect. ----------

Authority for an expenditure of $---------- Is requested for the purpose of ---------- (character of change) ---------- to the property of ---------- (Name of Owner)

that is now operated by ---------- (Name of Operating Company)

---------- (Place)
---------- (Date) 19----------

---------- (Name)
---------- (Title)

LOCATION OF PROJECT: Station or M.P. ----------; Division ----------

DESCRIPTION OF PROJECT: ----------

REASONS AND NECESSITY for the Extension, Improvement, or Other Changes: ----------

SUMMARY OF ESTIMATE.

ESTIMATED GROSS COST OF PROJECT. (before deducting Salvage) $----------
Amount Chargeable to Operating Expenses for Property Retired (Original Cost less Salvage) $----------
Value of Salvage recovered ----------
Original Cost of Property Retired (Actual or Estimated) $----------
Incidental Costs Chargeable to Operating Expenses (Including Cost of Removing Property Retired ----------
To other Accounts (Such as part cost Chargeable to other parties) ----------
Net {Charge / Credit} to Property Investment Account, Additions and Betterments $----------

Total Cost to be borne by ---------- (Name of Company)

RECOMMENDED ---------- (Name), ---------- (Title)
---------- (Name), ---------- (Title)

APPROVED ---------- (Name), ---------- (Title)
---------- (Name), ---------- (Title)

APPROVED AND AUTHORIZED ---------- (Name), ---------- (Title)

Date of Final Approval and Authorization ----------, 19----------

5. APPRAISALS, VALUATION RECORDS AND ACCOUNTING.

(a) *Authority for Expenditure* Form 1113

Construction, addition or betterment work should be authorized in accordance with a reasonable and simple system, involving the preparation of estimates of cost and the formal authorization of the expense by executive officers.

SPECIFICATIONS FOR FORM 1113.

Form as shown. Size 8½x11 inches. Printed on white medium bond paper; all lines and printing black.

INSTRUCTIONS FOR USE OF FORM 1113.

Request for Authority for Expenditure should be made for each change in the railroad's property involving an extension, addition, betterment, transfer of class of service, or retirement from service which, when signed by the highest approving officer, becomes an Authority for Expenditure. When properly prepared it should show:

1. The location of the project.
2. A brief and concise description of the project showing the character, magnitude and extent of the work.
3. Explanation of the reasons and necessity for the proposed changes.
4. Summarized distribution of the estimated cost.

So far as possible Authorities for Expenditure should be secured in advance of the changes in the property.

Involuntary changes in fixed property, such as destruction by storm, flood or fire, and other changes affected by emergency should be covered by an A.F.E. as soon thereafter as possible. A.F.E.'s covering the destruction of equipment should be made for each class at the end of each month.

A sketch showing the location and extent of the proposed changes should accompany and be made a part of the A.F.E. covering changes in fixed property.

A.F.E.'s should never overlap valuation sections. If a project, such as relaying rail, extends through or into two or more valuation sections, separate A.F.E.'s should be secured covering the changes in the property in each valuation section.

The expenditures under an A.F.E. must be kept within the amount authorized. Supplementary and additional Authority must be obtained in case of necessity.

Program authorities should expire at the end of the period for which they are granted.

A detailed estimate of the classified cost of the project should be prepared and accompany the Request for Authority. When the estimate is based upon plans, always refer to the numbers and dates of the plans.

Observe the following rules in describing projects:

(a) When additional buildings or other structures are to be built, begin the description with the word "New."

(b) When a building or other structure is to be built to replace an inferior one, or one of different kind, begin the description with the word "Replacing."

(c) In case of replacement, mention should be made of any variation from the original construction, such as:
    Substituting stone for frame building.
    Steel for wooden bridge, etc.

(d) When a building or other structure is reconstructed, retiring the original, use the word "Renewing."

(e) Under other conditions use a suitable word, such as:

Strengthening (Bridges)
Changing (Yard Tracks)
Altering (Buildings)
Extending or widening (Wharves)
Improvement at (consisting of new 20x40 foot frame passenger station, renewing 30x50 foot standard frame freight station, altering yard tracks, strengthening bridges, etc.)

Credits: When including in the estimate material which is to be used in temporary work, allow (under head of "Credits") an amount to cover estimated value of material to be recovered.

Disposition to be made of the abandoned buildings or other structures should be shown, if necessary, on the back of the form.

Dates of agreements, names of parties, etc., that are to be billed for items distributed to individuals and companies should be shown.

This form to be submitted in....................by the original officer to the approving officer. (The initiation and submission of R.F.A. papers as per special instructions of individuals roads.) If the Request for Authority is approved, designating number should be given and notice thereof should be sent out to all interested officials.

Size 8½x11 inches **Form 1114**

North & South Railroad

DETAILED ESTIMATE

A. F. E. No. ______
Sheet No. ______ of Sheets ______
Plan No ______ Reference ______
Office of ______ Date ______ 192 ______
Location and description of project ______

Quantity	Unit	Price	Description of Unit	Total Cost	Distribution of Estimated Cost			
					Road and Equipment		Operating Expenses	*
					Railroad	Railroad		
Totals								

Estimated by ______ Approved ______

Checked by ______ Approved ______

*Fill in Individuals and Companies, Profit and Loss, Miscellaneous Physical Property or other account titles as circumstances require.

(b) *Detailed Estimate Form* Form 1114

Specifications for Form 1114.

Form as shown. Size 8½x11 inches. Printed on white light bond paper; all lines and printing black.

Instructions for Use of Form 1114.

Each Request for Authority for Expenditure should be accompanied by a detailed estimate of the project on this form, unless the proposed change in the property is so small and so simple that it is deemed unnecessary to show the details of the estimate. It should be signed by the maker and approved by various officers in accordance with the prevailing organization. One copy to be attached to each copy of the A.F.E.

A complete estimate on this form should show:

1. Reference to the plan, if any—date, number and origin.
2. A brief and concise description and location of the project.
3. Estimate of cost in detail.
4. Credits, if any, for material to be recovered, etc., such as salvage from false-work, temporary tracks, and in case of a renewal on account of fire the amount of insurance recovered, and anything else that is a proper credit to the project.
5. Distribution of estimated cost as between Additions, Betterments, Renewals, Replacements, Retirements and between Other Companies and Individuals.
6. Ledger value, estimated if not known, of property which is to be retired.

(c) *Register of Authorities for Expenditure* Form 1115

Specifications for Form 1115.

Form as here shown. Size 14x17 inches. Printed on white medium ledger paper; all lines and printing black. Horizontal lines five to the inch.

Instructions for Use of Form 1115.

As each project is authorized, the number, date, location, description and estimated cost should be entered on this form in order of the numbers assigned. As the completion reports are submitted the remaining information called for on the form should be entered at once.

This form is designed to be kept in a lose-leaf binder. One book should be kept for each owning company.

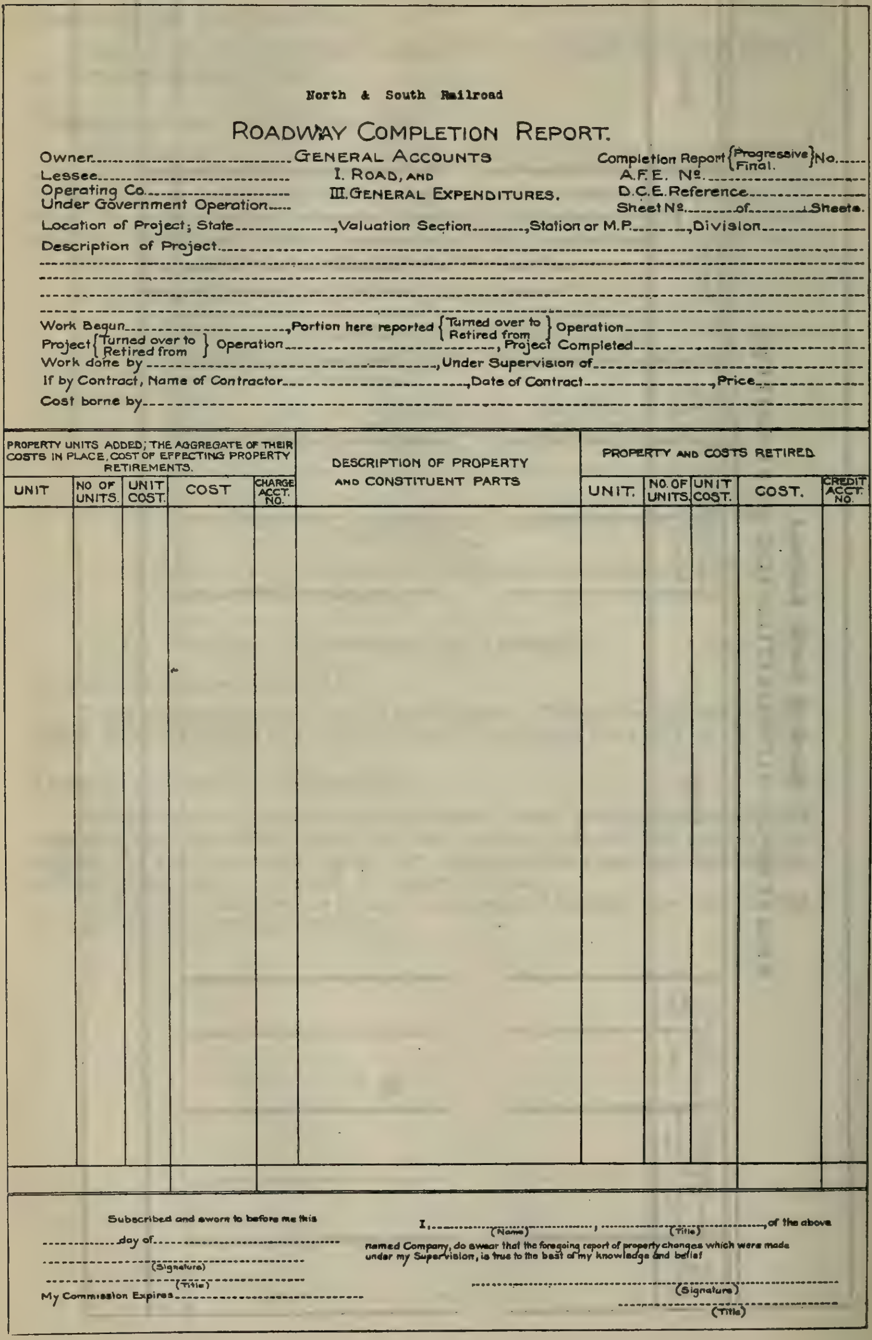
Form 1115

North & South Railroad
REGISTER OF AUTHORITIES FOR EXPENDITURE

Val Eng File No	Authority		Location		Descriptive Title	Date of Work		Compl Rep Rec'd	Total Costs		Remarks
	A. F. E.		State	Val. Sec		Beginning	Completion		Est	Actual	
	No	Date									

Size 11x17 inches

Form 1117



North & South Railroad

ROADWAY COMPLETION REPORT.

Owner................................ GENERAL ACCOUNTS

Lessee................................ I. ROAD, AND

Operating Co.......................... III. GENERAL EXPENDITURES.

Under Government Operation.....

Completion Report {Progressive / Final.} No.......

A.F.E. No..............................

D.C.E. Reference.......................

Sheet No.........of.........Sheets.

Location of Project; State................, Valuation Section.........., Station or M.P.........., Division..................

Description of Project...

Work Begun........................, Portion here reported {Turned over to / Retired from} Operation..............................

Project {Turned over to / Retired from} Operation..............................., Project Completed..............................

Work done by ...., Under Supervision of....................................

If by Contract, Name of Contractor..............................., Date of Contract..................., Price..............

Cost borne by..

PROPERTY UNITS ADDED; THE AGGREGATE OF THEIR COSTS IN PLACE, COST OF EFFECTING PROPERTY RETIREMENTS.					DESCRIPTION OF PROPERTY AND CONSTITUENT PARTS	PROPERTY AND COSTS RETIRED.				
UNIT	NO OF UNITS.	UNIT COST.	COST	CHARGE ACCT. NO.		UNIT.	NO. OF UNITS.	UNIT COST.	COST.	CREDIT ACCT. NO.

Subscribed and sworn to before me this

..............day of..................................

....

(Signature)

....

(Title)

My Commission Expires..............................

I, ... (Name), ... (Title), of the above named Company, do swear that the foregoing report of property changes which were made under my Supervision, is true to the best of my knowledge and belief

....

(Signature)

....

(Title)

Size 11x17 inches

Form 1118

North & South Railroad

Sheet No. ....of ....Sheets.

COMPLETION REPORT
OF
CHANGES MADE IN EQUIPMENT DURING THE SIX MONTHS ENDED......................19....
General Account 11. Equipment.

Authority	Equipment, unit numbers, names or series affected by the change.	Owner	Lessee.	Description of Equipment to which the change is applicable.	Total number of units affected.	Description of the change effected and of the other items contributing to the costs incurred.	Date of Change	COSTS INCURRED		COSTS RETIRED	
A. F. E. No.								Dr. Acct. No.	Amount	Cr. Acct. No.	Amount

I,.. ....of the above named company do swear that the foregoing report of property changes which were made under my supervision is true to the best of my knowledge and belief.
(Name) (Title)

Subscribed and sworn to before me this..........day of ....19.....

....
(Signature)

....My Commission Expires.......................................
(Title)

....
(Signature)

....
(Title)

(d) *Roadway Completion Report* Form 1117

Specifications for Form 1117.

Form as shown. Size 11x17 inches. All lines and printing black. Continuation sheets of same size may be used.

Instructions for Use of Form 1117.

A report must be made on this form for each project, as soon after completion as possible, showing in detail the changes made in the property, listing the units of property added and their costs and the units of property retired and their costs, and classified by accounts.

A plan must be made to accompany this form with notes showing location and extent of all new tracks laid; of old ones changed or removed; of bridges, buildings, platforms, stockyards, right-of-way fences, etc., built, changed, removed, or destroyed by fire, with date of fire. Measurements must be made to connect new work with definitely located points. Drawing should show both plan and profile or elevation of new tracks, bridges, buildings, etc. Show property of the company not changed under the improvement being reported by full black lines; property of the company removed, abandoned or destroyed, by dotted black lines; property of the company added, or new location, by full red lines; proposed but uncompleted work of the company by dotted red lines; and property of other railroads by other colors.

Care must be exercised in formulating the description of project to show the character, extent and magnitude of the change in property covered by the report.

(e) *Equipment Completion Report* Form 1118

Specifications for Form 1118.

Forms as here shown. Size 11x17. All lines and printing black.

Instructions for Use of Form 1118.

A report must be prepared on this form for each equipment project by the designated officer, as soon after completion as possible, listing and describing the units of equipment affected and giving careful description of the changes made and listing the units involved, both added and retired, with the costs of each. If a project involves changes in a number of units completed in more than one six months' period a progress report should be made covering the changes completed in each six months' period. When the whole project is finished a final report shall be prepared covering all the changes made under the A.F.E., which will be summary of all the semi-annual progress reports.

6. Labor and General Forms.

(a) *Time Roll* Form 1119

Specifications for Form 1119.

Form as shown. Size of book, 5½x8½ inches. Cover to be of three-ply manila paper, book proper to be on yellow paper; printing to be in black. Book to contain 12 pages. Form shown is reduced size.

(e) *Equipment Completion Report* Form 1118

Specifications for Form 1118.

Form as shown. Size 11x17 inches. All lines and printing black.

Instructions for Use of Form 1118.

A report must be prepared on this form for each equipment project by the designated officer, as soon after completion as possible, listing and describing the units of equipment affected and giving careful description of the changes made and listing the units involved, both added and retired, with the cost of each. If a project involves changes in a number of units completed in more than one six months' period a progress report should be made covering the changes completed in each six months' period. When the whole project is finished a final report should be prepared covering all the changes made under the A.F.E., which will be a summary of all the semi-annual progress reports.

7. Labor and General Forms.

(a) *Time Roll* Form 1119

Specifications for Form 119.

Form as shown. Size of book, 5½x8½ inches. Cover to be of three-ply manila paper, book proper to be on yellow paper; printing to be in black. Book to contain 12 pages. Form shown is reduced size.

Form 1119

NORTH AND SOUTH RAILROAD

Sub-Division No. ....

TIME ROLL

OF

Section No. .... or ....
(Name or Number of Gang)

..............................Month of .... 19....

I hereby certify that the within returns are correct:

Examined and found correct: ....
FOREMAN

Supervisor of ....

Form 1119

DAILY RECORD OF TIME

____
(Name of Railroad)

RECORD OF TIME FOR THE MONTH OF ______________ 19__

Badge No.	Name	Occupation	Periods																Total		Rate		Amount Earned	Totals	Deductions			Total Paid	Pay 1st Period	Pay 2nd Period	Time Check Number
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		Month	Hours	Per Mo.	Per Hr.			Account	Amount	To Whom Paid				
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31													
	Regular Overtime Overtime (Penalty)																														
	Regular Overtime Overtime (Penalty)																														

1. Spell names correctly. Write out first name and give middle initial. Enter check number in check number column.

2. Write "Paid by Certificate," when men have been so paid. If hired again, enter name a second time.

3. Amounts due each man must be in even five (5), or ten (10) cents.

4. Time of monthly men, not working a full month: Multiply the rate per month by the number of days worked (including Sundays and holidays) and divide by the total number of days in the month.

Form 1119

RECORD OF WORK DONE ON DAYS OF THE MONTH

DAY	KIND OF WORK AND WHERE PERFORMED	HOURS
1		
2		
3		
4		
5		

RECORD OF WORK DONE ON DAYS OF THE MONTH

DAY	KIND OF WORK AND WHERE PERFORMED	HRS.
31		

SUMMARY OF WORK DONE FOR MONTH

ITEMS	DISTR.	HOURS	RATE	AMOUNT	

I certify the foregoing to be correct,

....*Foreman.*

Examined and approved,

....*Supervisor.*

NOTE.—Spaces to be provided for 31 days.

CONTRACT AND LEASE RECORD.

Form 1120

CONTRACTS AND LEASES

100 Pages

Number	Name of Road	With Whom	Nature of Document		Date			Expires			No. of Canceled Contract	Memoranda

RECEIPTS FOR CONTRACTS AND LEASES REMOVED FROM FILES.

50 Pages

Number	Name of Road	With Whom	Receipt	When taken			When returned			

RECEIPTS FOR CONTRACTS AND LEASES REMOVED FROM FILES.

Number	Name of Road	With Whom	Receipt	When taken			When returned		

REFERENCES TO CONTRACTS AND LEASES, SHOWING DATE OF EXPIRATION

6 Pages

JANUARY																	
1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	

REFERENCES TO CONTRACTS AND LEASES, SHOWING DATE OF EXPIRATION

FEBRUARY																
1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913

(b) *Contract and Lease Record* Form 1120

SPECIFICATIONS FOR FORM 1120.

The Custodian of Leases should keep a Contract and Lease Record Book, containing in the body of the book a full record of the leases in accordance with the form illustrated.

In the back part of the book twelve pages for the twelve months should be ruled into columns for years.

INSTRUCTIONS FOR USE OF FORM 1120.

Leases should be numbered and filed in numerical order, by road, branch or division, in a fireproof vault.

Immediately after the receipt of a lease it is entered in the body of the book; the lease number should be entered under the year on the proper month page when it expires.

The name of the lessees should be indexed alphabetically in the front of the book, and each lease should be indexed by the station name.

A few pages in the back of the book should be used for the purpose of keeping a record of the leases removed from the files.

A receipt should be required for each contract or lease removed from the files.

(c) *Register of Title Deeds*

D. V. Forms 107 and 108 were prescribed by Order No. 7, Bureau of Valuation, Interstate Commerce Commission, and it is recommended that these forms be kept up to date for a Register of Title Deeds.

[4]MAPS, CHARTS AND PROFILES

(a) *Specifications for Maps and Profiles.*

SIZE

Right-of-Way and Track Maps

Twenty-four inches by 56 inches; single-line border 23 inches by 55 inches.

Station Maps

Twenty-four inches by 56 inches; single-line border 23 inches by 55 inches. When more than one sheet is required to show a station property, the plat shall be made upon "match-marked" sheets in such manner as to require the minimum number.

Record Profiles

Plate "A" tracing cloth 12 inches by 56 inches; single-line border 10 inches by 55 inches.

All other sizes of drawings to be determined by each individual road and to be as far as possible multiples of correspondence size or other basic units.

SCALES

Masonry and Building Plans

One-eighth inch, ¼ inch or ½ inch equals one foot.

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[4]Adopted, Vol. 18, 1917, pp. 759-768; Vol. 19, 1918, pp. 209, 1105.

Detail Plans of Buildings

Scales should depend upon character of plans.

Right-of-Way and Track Maps

One inch equals 100 feet, or 200 feet or 400 feet, but the same scale should be used throughout each Valuation Section.

Station Maps and Track Layouts

One inch equals 100 feet, or, in complicated situations, one inch equals 50 feet.

Individual Right-of-Way Maps

One inch equals 200 feet, 100 feet or 50 feet, as may be necessary.

Maps of Surveys

One inch equals 400 feet or 200 feet when practicable, and when necessary one inch equals 100 feet. Reductions of same, one inch equals 1000 feet.

Profiles

Plate "A" vertical, one inch equals 20 feet; horizontal, one inch equals 400 feet, except on ballast profiles, the vertical scale to be one inch equals 4 feet.

Condensed Profiles

Vertical, one inch equals 200 feet; horizontal, one inch equals one mile, except where other scales are necessary.

Track Charts

Horizontal, one inch equals one-half mile; vertical, one inch equals 100 feet or 400 feet.

TITLES

The title to be placed as near the lower right-hand corner as practicable.

The following information to be shown for right-of-way and track maps, station maps and record profiles.

(1) Class.
    (a) Right-of-way and track map.
    (b) Station map.
    (c) Profile.
(2) Corporate name of railway.
(3) Name of operating company.
(4) Name of railway division or branch line.
(5) Beginning and ending of survey station numbers on sheet.
(6) Scale or scales.
(7) Date as of which maps or profiles represent the facts shown thereon.
(8) Office from which issued.

Titles for all other drawings to conform to the practice of each individual road.

A note referring to drawings, note-books or other data used in compiling to be shown on each drawing.

ORIENTATION

The tops of maps should be to the north or east, according as the general direction of the line is east and west or north and south.

(The existing stationing to be preserved wherever practicable, adjacent stationing being extended in the same direction over unstationed intervals.)

On each end of each sheet there shall be shown a pointer directing to a terminal or important station.

SYMBOLS

The symbols used on all maps, profiles and plans shall be the standards recommended by the American Railway Engineering Association, in so far as they may be applicable.

CARDINAL POINTS

On all maps an arrow showing the true north and south line (as nearly as can be ascertained from existing records) shall be placed.

COLORS

On all maps and profiles to be submitted to the Interstate Commerce Commission, black only shall be used, except that the ruling of profiles shall be in orange ink.

INFORMATION TO BE SHOWN

Maps of Surveys

Show all surveyed lines; points of curve to be marked by radial lines, on which stations and plusses are to be given. Legends to be placed between the radial lines, giving the degree and central angle of simple curve and central angle of each spiral. Also show the contours where necessary at intervals of five (5) feet; all streams, rivers, etc., indicating direction of current of same by arrows, and approximate area of opening required. Also property lines, buildings of all kinds, pole and pipe lines, fences, roads, existing railroads, bridges, drains, sewers, manholes, conduits, culverts, areas of existing openings below high-water marks and any other necessary data within the limits of the survey. Names of cities, towns and stations; county, township and state lines to be distinctly marked. The distance from each end of the survey to some point easily located on county or state map, or when survey connects with an existing railroad, name of and distance to nearest station to be given.

Where tracks are shown, points of switches and points of frogs to be marked, and frog numbers noted.

When they are extensive, surveys are to be placed by co-ordinates determined by observations taken every seven (7) miles easting or westing on location and every fifteen (15) miles on preliminary work; corrections of one minute (0° 1′) for every 7000 feet of easting or westing shall be made in bearings for convergence of meridian, the first correction to be made at a convenient point about 3000 feet from point of observation. If the bearings of the tangent at the point where the correction is to be made is northeast or northwest, add one minute (0° 1′) for correction of azimuth; if it is southeast or southwest, subtract one minute (0° 1′).

Both bearings shall be shown on the tangent whose bearing is corrected and "(0° 1′) added (or subtracted) for correction of azimuth" shall be marked along the meridian through the point of correction. Corrected bearings shall be accepted as the true bearings of lines.

Profiles of Surveys

Show ground lines, surface of streams, rivers, etc., depth of same, elevations of high and low water line, subgrade lines showing rate of grade and elevations at all points of change of rate and station numbers.

One line below profile show alinement using full line for tangents and broken lines for curves, showing degree and direction of same, total deflection and plusses at beginning and ending of simple curves and spirals.

Divisional lines shall be shown on this alinement, and names of property owners.

Give distances from ends of profile to nearest city, town or station.

When estimates are shown, note width of roadbeds and list quantities in cuts and fills, tunnels, bridges, pipes, crossings, etc., classified in the order given on estimate sheets. Also table of quantities for each section.

All elevations shall refer to U. S. Geological Survey Datum or other Government precise level bench marks based on sea-level datum.

Culture Maps

To be tracings from the original maps of surveys of new lines, without the contours, for adoption by the Board of Directors, and to be filed in the offices of the secretaries of the states and clerks of counties when required by law.

Track Layouts

Tracks in all cases to be represented by single lines, except on plans of 50-foot scale or larger; where it is necessary to show the rails, double lines may be used. Indicate each track on the interlocking plans by a double line.

Record Plans

Masonry

All masonry records to be drawn to such a scale as will show clearly all dimensions as built, elevations of foundations, neat lines, bridge seats, base of rail, surface of water and ground line. Length of piles or elevation of points and number driven.

Clearance to be shown when crossed by railroad, road or street. In all cases give quantities in final estimate, location and station numbers.

Certificate

A certificate as to the correctness of all maps and profiles to be filed with the Interstate Commerce Commission shall be printed and executed on the first sheet of each series, and each of the other sheets of the same series shall be identified as a part thereof. The certificate on the first sheet of each series shall be placed as near the title as practicable and shall be in the following form:

State of..................................
County of..................................

I, the undersigned, officer of the..., do hereby
(Name of Railway Co.)
certify that this is a correct....................................in a series of..........
(Map or Profile)
sheets of said railway from survey station...to
survey station..State of
(Main Line, Division or Branch)
...., prepared from the records of said company.

....
Engineer.

Correct:

....
(Name of officer authorized to certify records.)

Subscribed and sworn to before me this...day
of..................................

....
Notary Public in and for the
County of ....
State of ....

My commission expires..................................

The identification on the other sheets of a series shall be of the following form and placed as near the title as practicable:

Sheet No. .... of............ of..................................
(Series) (Railway, main line or branch)
from survey station...................... to survey station......................

....
Engineer.

RIGHT-OF-WAY AND TRACK MAPS

A right-of-way and track map shall be a true horizontal projection of the right-of-way, tracks and other structures platted continuously between district or terminal points.

For each series of right-of-way and track maps there shall be made a small skeleton index map on a scale of not less than ¼-inch equals one mile. Where practicable this index map may be placed on any vacant space of the first sheet of the series, and where made on a separate sheet it shall be 24 inches by 56 inches. This index map shall show by outline with file numbers therein the sheets of a series, the name of main line, division or branch line, the principal towns or cities and the beginning and ending station numbers of series, and any other information proper to place thereon.

All right-of-way and track map sheets shall be numbered serially, beginning with Sheet 1. The sheets representing valuation sections shall form separate series, and the valuation sections shall be numbered serially with the letter "V" preceding the number. Index numbers shall be in the lower right-hand corner of the sheet and enclosed in plain, single line circle one inch in diameter. Valuation section numbers shall be in the upper half of the circle and sheet number below with a straight line between.

On all right-of-way and track map sheets references to all station maps shall be shown by outlining limits of station maps and giving the number of the station map sheets.

The file number shall also be placed on all map sheets in the lower left-hand corner.

Corrections should be made whenever any changes are made in any of the features shown thereon, and at stated periods a corrected copy sent to the proper office.

On track maps drawn to a scale of one inch equals 50 feet or less, tracks should be represented exclusively by double lines.

On track maps drawn to a scale of one inch equals 200 feet or more, tracks should be represented exclusively by single lines.

On track maps drawn to a scale of one inch equals 100 feet; (a) on maps representing preliminary studies and designs of proposed track layouts, tracks may be represented by single lines. Double lines should be used where considered necessary to show turnout details; (b) on maps representing completed work, station plats and permanent records, tracks should be represented by double lines.

STATION MAPS

The station maps shall be supplemental to the right-of-way and track maps for terminals and other locations where the property is so extensive and complicated that it cannot be clearly shown thereon.

The station maps shall be made as prescribed above for the right-of-way and track maps.

When more than one sheet is required to show a station property, the plat shall be made upon "match-marked" sheets in such manner as to require the minimum number.

The station maps shall be given the same serial number preceded by the letter "S" as the sheets of the right-of-way and track maps which they supplement.

In case a right-of-way and track map sheet is supplemented by more than one station map, a subscript letter should be used after the number, e. g., S 32_a, etc., where land and track features are combined; S-L 32_a, etc., where land only is shown; and S-T 32_a, etc., where track features only are shown.

The purpose of the large scale station maps is to permit the showing of improvements in more detail than is practicable on the right-of-way and track map.

Where the station property to be mapped is extensive and complicated, it may be delineated on two separate maps.

(1) Shall show all data relating to ownership of lands.

(2) Shall show all tracks and structures and external land boundaries.

Where practicable, without sacrificing the clearness of the map, the two may be combined into one map, or one class of property may be shown on the right-of-way and track map and the other on the station map.

Arrangement of Data on Right-of-Way and Track Maps and Station Maps

The general direction of the center line of track shall be as nearly as possible parallel to and half-way between the long sides of the sheets, so that the maximum space each side of the platted right-of-way lines may be available for showing adjacent topography and property lines and for making notes as to physical property. The maximum length of main roadway represented on any one sheet (between "match-marks") shall be two miles, if scale is one inch equals 200 feet, or in proportion thereof if other scales are used.

On them shall be shown the following data:

(a) Boundary Lines of All Right-of-Way

The term right-of-way as herein used includes all lands owned or used for purposes of a common carrier, no matter how acquired.

Show: Width of right-of-way, in figures, at each end of the sheet and at points where a change of widths occurs, with station and plus of such points; boundary lines and dimensions of each separate tract acquired; a schedule of deed, custodian's number, the name of the grantor and grantee, kind of instrument, date and book page where recorded. Each tract of land shall be given a serial number and listed serially in the schedule. The schedule shall also include references to leases to the company, franchises, ordinances, grants and all other methods of acquisition.

(b) Boundary Lines of Detached Lands

Where same can be shown clearly. The term "detached lands" as herein used includes:

(1) Lands owned or used for purposes of a common carrier, but not adjoining or connecting with other lands of the company.

(2) Lands owned and not used for purposes of a common carrier, either adjoining or disconnected from other property owned by the company.

Show: Boundary lines and dimensions; distance and bearing from some point on the boundary lines to some established point or permanent land corner, where practicable, and separately on the schedule above, the lands not used for purposes of a common carrier.

(c) Intersecting Property Line of Adjacent Land Owners

Where the information is in possession of the company or can readily be obtained, show: The property lines of adjacent land owners, the station and plus of important intersections of property lines with center line of railway or other railway base line, and the names of the owners of the land adjacent to the right-of-way.

(d) Intersecting Divisional Land Lines

Show: Section, township, county, state, city, town, village or other governmental lines, with names or designations; the width and names of streets and highways which intersect the right-of-way, and the station and plus at all such points of crossings or intersections with center lines of railway or other railway base line.

(e) Division and Sub-Division of Lands Beyond the Limits of the Right-of-Way

Where the information is in possession of the company, show: The section and quarter-section lines for a maximum distance of one mile on each side of the center line or base line of railway where the land has been sub-divided into townships and sections; such data as to divisions, tracts, streets, alleys, blocks and lots, where the land has been divided in some other way than by sections; the distance, where known, from railway base line to permanent land corners or monuments, and the base line from which the railway's land was located (center line of first, second, third or fourth main track or other base line).

(f) Alinement of Tracks

Show: The center line of each main and sidetrack and distances between them; the length, in figures, of all sidetracks from point of switch to point of switch, or point of switch to end of track; all street car lines and other railways, crossed (with angle of crossing) or connecting, and state if crossing is over or under grade, and give name of owner of such tracks; survey station number at even 1000 scale-feet intervals, and station and plus at points of all main line switches, at points of curves and tangents and at beginning and ending points on each sheet; the degree and central angle of curves and joint tracks and ownership thereof. On right-of-way and track maps inside the limits covered by the station maps it will not be necessary to show the sidetracks when to do so will obscure more important data.

(g) Improvements

Show: Station and office buildings, shops, engine houses, turntables, fuel stations, water stations, etc. (owned by the company), in general outline, where it can be done clearly. Also indicate conventionally: Bridges, trestles, culverts, tunnels, retaining walls, stock guards, mileposts, signals of all kinds and signal bridges and ground masts, wire lines of all kinds and supports, fences by note only, and other principal railway structures owned by the company, with general data as to dimensions, and character thereof and location with reference to main or sidetracks, and where practicable, pipe lines, sewers, underground conduits, paving, curbing or similar works located on right-of-way or adjoining and owned by the company in whole or in part. Give station and plus to all important structures which are outlined above.

(h) Topographical Features

Show: Rivers and creeks, water courses, with arrows showing direction of current, highway crossings, etc. Give names, where known, and when highway crossings are over or under grade, so state.

Show all other surface and subsurface improvements not hereinbefore noted, as far as may be practicable.

PROFILES

The profile shall be a vertical, sectional view on center line of track (or other railway base line) on an exaggerated vertical scale, and shall show the features of the railway track substructure and superstructure which can best be indicated in vertical projection; also such other detail information as is hereinafter more fully set forth. The elevation of surface of water in rivers and streams and flood lines shall be shown also, where it is possible to do so. All elevations to refer to U. S. Geological Survey Datum or other Government precise level bench marks based on sea-level datum.

Profiles shall be made and numbered serially, beginning with sheet No. 1 so that any serially numbered sheet shall cover the same portion of the railway as the like serially numbered sheet or sheets of the right-of-way and track maps. The sheets representing valuation sections shall form separate series, and valuation sections shall be numbered serially with the letter "V" preceding the number, and the letter "P" shall precede the serial number or numbers of the sheets. Index numbers shall be in the lower right-hand corner of the sheet and enclosed in a plain, single line circle one inch in diameter.

Valuation section numbers shall be in the upper half of the circle and sheet number or numbers below with a straight line between.

The file number shall also be placed on all profile sheets in the lower left-hand corner.

Platting shall be done as specified for right-of-way and track maps.

The 2½-inch space immediately above the lower border line shall be used for track alinement and topographic data. The remaining 7½-inch space shall be used for platting in such a way as to most economically utilize the space.

The following data shall be placed on all profiles:

(a) Roadway

Show: The vertical projection of the original ground surface on center line of railway; present grade line (top of the roadbed subgrade); rates of grade; elevations (sea-level datum) at all points of change of grade, at end of sheets and where profile is "broken," at 50-foot (scale) intervals; and the station and plus to points of change of grade and station numbers at each 1000-foot (scale) interval near lower border of sheet.

(b) Structures

Show: Bridges, trestles, culverts, retaining walls, tunnels and other roadbed structures in vertical projection, stating the kind and general dimensions by figures; average depth of penetration of piling in each bent of trestles, or under other structures, by vertical projection; character of, and depth of foundation bed of masonry structures by vertical projection; reference to railway file numbers of the detail standard or special plans by which the structures were built; existing mileposts and the station and plus of each of the above-indicated improvements.

(c) Quantities

Profiles shall show for each mile a summary of construction quantities to subgrade, including roadway, bridges and culverts.

The summary of quantities shall be in detail, according to the standard classification of units used by the company.

(d) Alinement and Track

Show: On the lower 2½x55-inch space of the profile sheet, the center line of each main track, developed into straight line or lines, with alinement notes of curves stated in figures; the station and plus at points of curves and tangents, and other data, such as passing tracks, depot buildings, water and fuel stations, highway crossings, railway crossings and important water courses that will assist in interpreting the profile. For platting transversely, a scale of one inch equals 200 feet shall be used.

[5]TRACK CHART

A Track Chart showing complete information respecting the grade, alinement and other physical features of a railway is necessary, and the "Track Chart," Form 1121, is recommended.

[6]PROGRESS PROFILE

A profile showing complete information respecting the rate of progress of work pertaining to the different features of a railway is necessary, and the standard "Progress Profile," Form 1122, is recommended.

[7]SPECIFICATIONS FOR THE DESIGN, ARRANGEMENT AND PRINTING OF FORMS

Purpose of Forms

(1) The purpose of a form is to provide a convenient means for recording facts or statements in a systematic manner.

General Requirements

(2) Forms should be made as simple as possible so that they may be readily understood and easily filled out. No more information should be called for than is absolutely required.

Temporary or Permanent Forms

(3) Forms may be for temporary use or permanent record. Temporary forms do not always require as complete data and may be printed on cheaper paper.

Form Number

(4) Each form should be given a number. This number should be printed in small type in one top corner—left preferred.

Name of Carrier

(5) The name of the carrier should be printed on permanent forms and on temporary forms which pass from one department to another.

Office Originating Report

(6) Designation of the office originating the report or statement should be shown, such as "Office of (title), (location)." This should appear below the name of the carrier.

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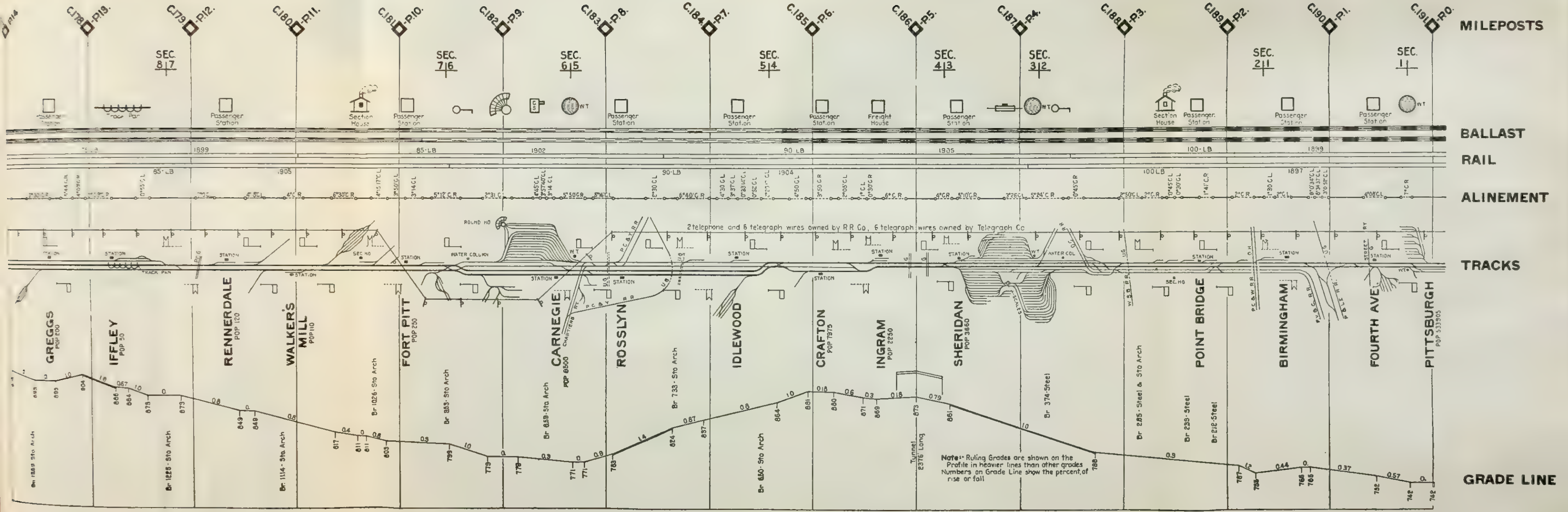
[5] Adopted, Vol. 8, 1907, pp. 111, 112, 114, 116-120, 132.

[6] Adopted, Vol. 7, 1906, pp. 278, 280, 328, 329.

[7] Adopted, Vol. 30, 1929, pp. 579, 1465.

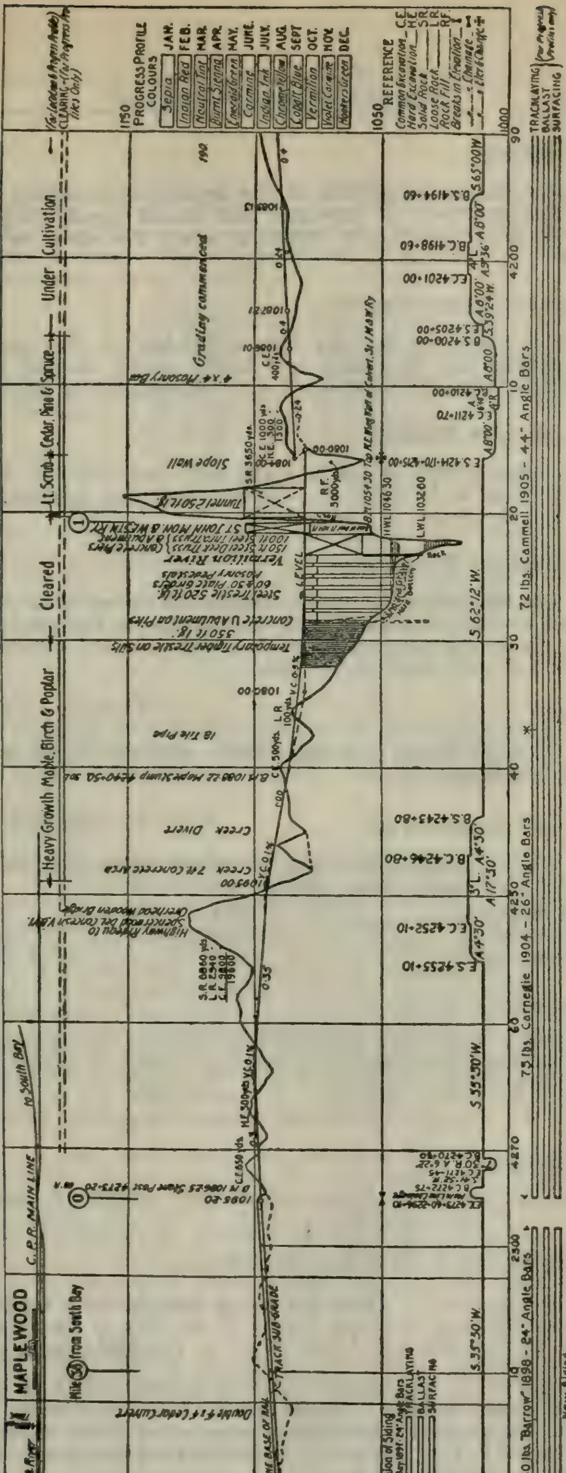
TRACK CHART

Form 1121



Form 1122

PROGRESS PROFILE



Caption of Form

(7) The heading or caption of the form should indicate the character of the report or the statement and should appear in large type. This should follow the words indicating where the report or statement was made.

Headings and Column Captions

(8) It is important that the title or heading of the form and the column headings also be clearly and briefly stated, so that the person filling out the form will understand what information is wanted.

Column and Line Spacing

(9) Column widths should be made with respect to the figures and for the wording to be filled in. Column and line spacing should be arranged for typewriter or handwriting.

Column and Line Numbering

(10) For the larger and more complicated forms, it is desirable to number each vertical column and each horizontal line. The column numbers should be placed immediately below the caption of the column and the line numbers at both ends of the line.

Guide Lines

(11) On many forms, it is desirable to rule every third or fifth line heavier or a different color.

Prepared and Approved by

(12) Where desirable, forms should provide spaces in a suitable place, such as the lower right corner, similar to:

Compiled by .... Date 193
Checked by .... Date 193
Approved by .... Date 193

Sheet Numbering

(13) When more than one sheet is required for a report, space should be provided, preferably in upper right corner, to show the number of sheets in the series, such as

Sheet .... of .... sheets.

Binding Margin

(14) It is desirable to leave at least 1¼" on the side intended for binding.

Printing Instructions for Filling Out Forms

(15) Instructions for filling out forms may be on a separate sheet, or printed on the back or at the bottom of the face of the form. If the form is to be available for blueprinting, as provided for in paragraph (20), the instructions should not be printed on the back. When there may be doubt as to the manner in which entries should be made, the instructions should include a sample form wholly or partially filled out with typical entries clearly illustrating its use, or a form on which there has been printed in the columns or on the lines the instructions for filling out the specific column or line.

Size

(16) Each carrier should adopt a standard size and all forms should be either this standard size or multiples thereof. The size to be adopted should be such that there is no wastage in cutting and should also fit standard filing cabinets. The standard sizes of paper which may be cut to the best advantage are as follows:

	Inches		*Inches*
Cap	14 x 17	Folio	17 x 22
Double Cap	17 x 28	Double Folio	22 x 34
Double Double Cap	28 x 34	Medium	18 x 23
Crown	15 x 19	Double Medium	23 x 36
Double Crown	19 x 30	Royal	19 x 24
Demy	16 x 21	Double Royal	24 x 38
Double Demy	21 x 32		

Color of Lettering and Lines

(17) Where lettering and lines are *printed* (not ruled) one color (black preferred) should be specified. Spaces or sections may be separated by a heavier or a double thin black line rather than by a colored line. When the lines are pen ruled, different colored lines may be used, such as red and blue on white paper and brown and green on buff paper.

Punching

(18) When intended for a loose-leaf binder, consideration should be given to punching or making the places for the binding holes to fit the binders intended to be used. When the type of binder to be used is known, the forms should be pre-punched. This will facilitate filing.

Quality and Weight of Paper

(19) Paper is made from two basic substances, namely, rags or wood pulp. Wood pulp paper is suitable only for inter-office or temporary forms. Forms for permanent record should be printed on paper with rag content of thirty per cent or better. The paper should be durable and tough and flexible enough to crease without cracking. It should be of a grade which will not fade or turn yellow with age and should stand several erasures without allowing the ink to show through on the reverse side. The weight of the paper should receive consideration as economies may be effected through preparation at one writing of sufficient copies to complete the records in all offices requiring the report. In this connection it may be pertinent to quote paragraph 1741 appearing on page 518 of the 1928 edition of "Railway Accounting Procedure" published by the Railway Accounting Officers' Association.

> "It has been found that railroads do not avail themselves of the economies which are practiced in many other lines of business, through the preparation at one writing of a sufficient number of copies of essential reports to complete the records in all offices in which the information contained in the reports is required or is filed. Economies which may be effected by more general use of copies of original reports are suggested to all railroads."

Blueprint Reproductions

(20) It is well to anticipate that some reports or statements made on forms may be reproduced by blueprinting. In such cases consideration should be given to the kind of paper and the instructions should provide that, when typing, black carbon paper, reversed, should be laid against the reverse side. The typewriter ribbon used should be black record.

Methods of Printing

(21) The principal methods of printing are as follows:

1. Mimeograph
2. Multigraph
3. Printer's type and printed lines
4. Printer's type and pen ruling
5. Hand lettering and lithographic printing or photo-printing from zinc and copper plates.

Economy in printing can often be obtained by group printing. Under this procedure, several different forms are run through the press and printed at the same time on large sheets or rolls of paper which are afterward cut to the required size for each form.

Padding Forms

(22) To avoid wastage through soiling or wrinkling, forms which are in frequent use should be made up in pads of fifty or one hundred sheets.

Cards

(23) Cards are sometimes preferable to sheets for permanent records. Use should be made of standard stock sizes where practicable, such as:

3″ x 5″; 4″ x 6″; or 5″ x 8″

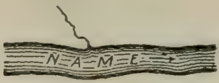
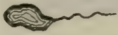
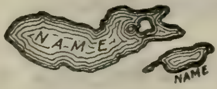
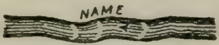
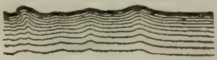
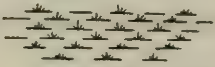
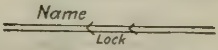
Because many cards are subjected to much "fingering" they should be of good quality rag content. The use of celluloid tab covers or guides is recommended to protect the parts of the cards most subject to wear. Specifications for paper forms referred to in other parts of this report should also be considered when designing printed and/or ruled cards.

A Forms Committee on Each Railroad

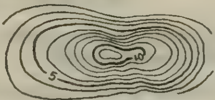
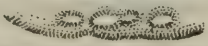
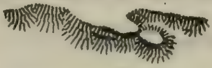
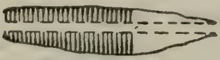
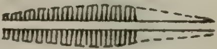
(24) It is recommended that each carrier establish its own "forms committee," which committee should have authority to design and/or approve all new forms or changes in established forms.

[8]CONVENTIONAL SIGNS FOR USE ON RAILWAY PROFILES, RIGHT-OF-WAY AND TRACK MAPS

HYDROGRAPHY.

Stream	
Springs and Sinks	
Lakes and Ponds	
Falls and Rapids	
Water Line	
Marsh	
Canals	
Ditches	Size

RELIEF.

Contour System	
Sand	
Cliffs	
Cut	
Embankment	
Top of Slope	Medium
Bottom of Slope	Fine

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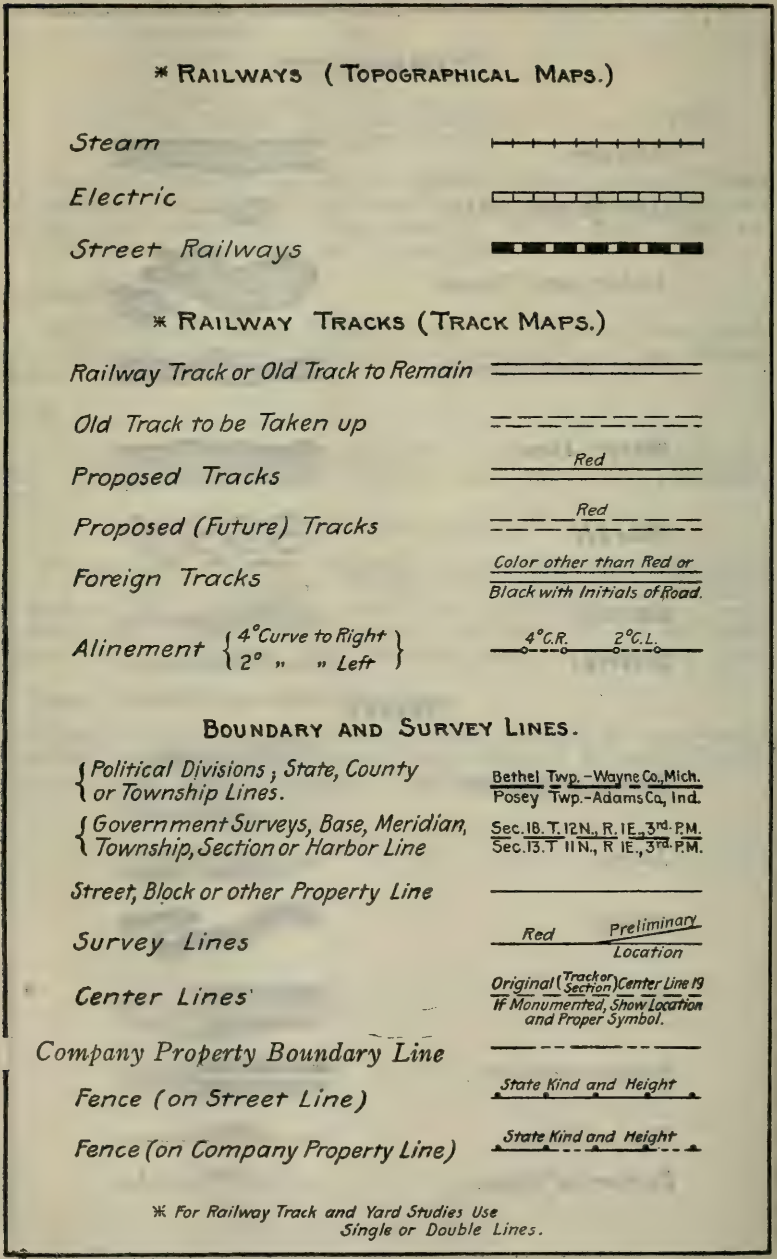
[8] Adopted, Vol. 15, 1914, pp. 930-940, 1160; Vol. 16, 1915, pp. 789, 1086, 1087.



* RAILWAYS (TOPOGRAPHICAL MAPS.)

Steam	
Electric	
Street Railways	

* RAILWAY TRACKS (TRACK MAPS.)

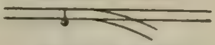
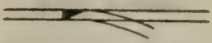
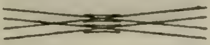
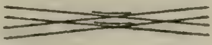
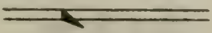
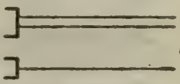
Railway Track or Old Track to Remain	
Old Track to be Taken up	
Proposed Tracks	*Red*
Proposed (Future) Tracks	*Red*
Foreign Tracks	*Color other than Red or* *Black with Initials of Road.*
Alinement { *4° Curve to Right* *2° " " Left* }	*4° C.R.* *2° C.L.*

BOUNDARY AND SURVEY LINES.

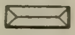
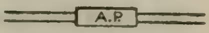
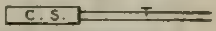
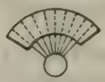
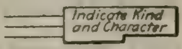
{ *Political Divisions; State, County* *or Township Lines.*	Bethel Twp.-Wayne Co., Mich. Posey Twp.-Adams Co., Ind.
{ *Government Surveys, Base, Meridian,* *Township, Section or Harbor Line*	Sec. 18. T. 12 N., R. 1 E., 3rd P.M. Sec. 13. T. 11 N., R. 1 E., 3rd P.M.
Street, Block or other Property Line	
Survey Lines	*Red* *Preliminary* *Location*
Center Lines	*Original (Track or Section) Center Line 19* *If Monumented, Show Location and Proper Symbol.*
Company Property Boundary Line	
Fence (on Street Line)	*State Kind and Height*
Fence (on Company Property Line)	*State Kind and Height*

* *For Railway Track and Yard Studies Use Single or Double Lines.*

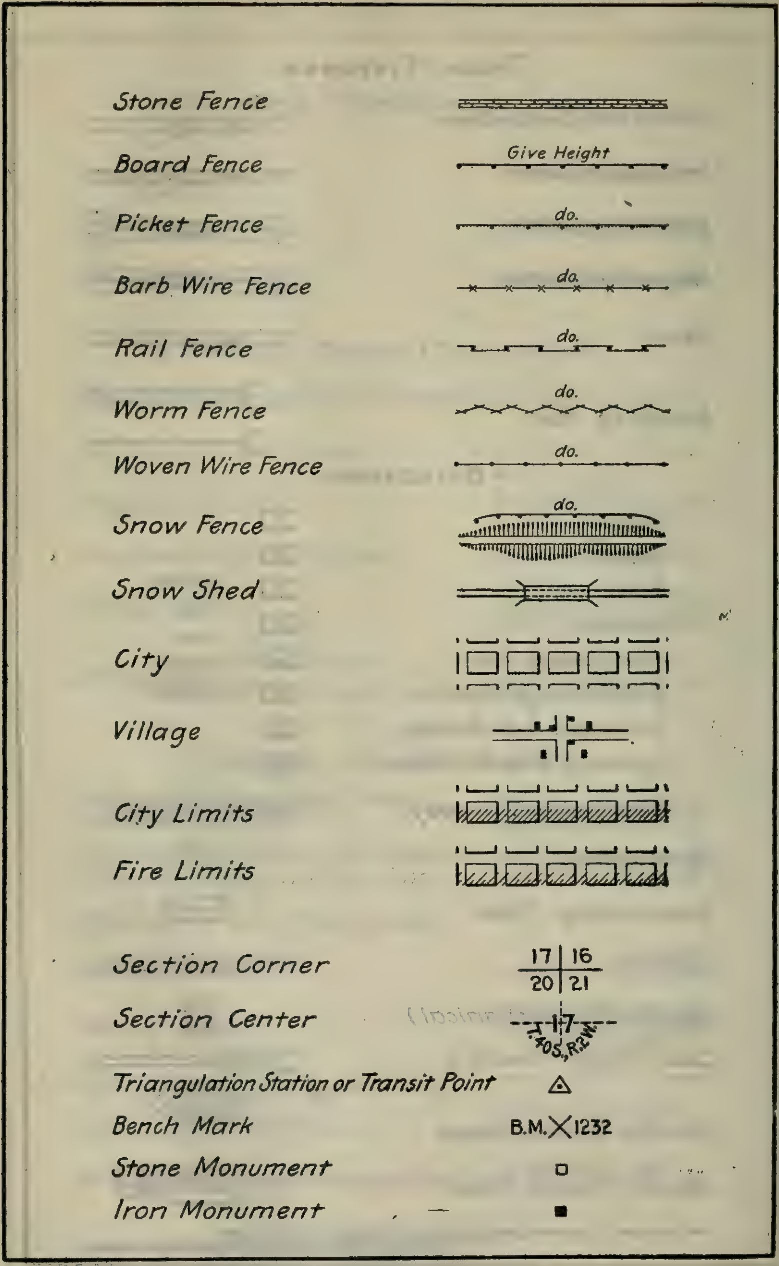
TRACK FIXTURES.

Turnout and Switch-Stand	
Interlocked Switch	
Double Slip Switch	
Single Slip Switch	
Derail	
Bumping Post	

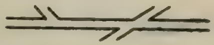
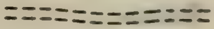
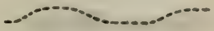
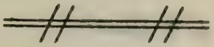
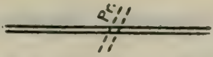
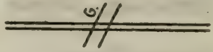
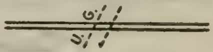
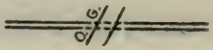
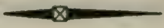
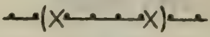
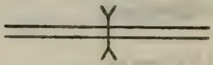
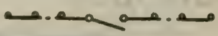
* BUILDINGS.

Stone	S	
Frame	F	
Brick	B	*Indicate Use and Number of Stories.*
Concrete	C	
Corrugated Iron	Cor I	
Brick Passenger Station	B.P	
Electrical Sub-Station	S.S	
Lightning Arrester House	L.A	
Platform or Driveway	*Indicate Kind and Character*	
Turntable		
Interlocking Tower		
Ash Pit		
Coal Chute (Mechanical)		
Coal Chute (Trestle)		
Circular Engine House		
Square Engine House		

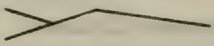
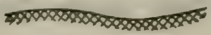
* *Indicate Type and Construction by Combination of Letters, as:*
F.F.= Freight Frame Station, B.F.= Brick Freight Station.


Stone Fence
Board Fence
Give Height
Picket Fence
do.
Barb Wire Fence
do.
Rail Fence
do.
Worm Fence
do.
Woven Wire Fence
do.
Snow Fence
do.
Snow Shed
City
Village
City Limits
Fire Limits
Section Corner
17 16
20 21
Section Center
17
T.40S.,R2W.
Triangulation Station or Transit Point
Bench Mark
B.M. 1232
Stone Monument
Iron Monument

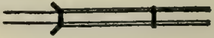
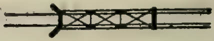
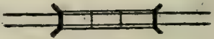
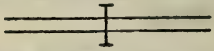
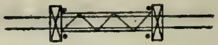
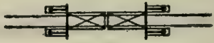
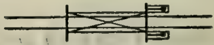
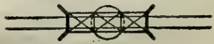
HIGHWAYS AND CROSSINGS.

Public and Main Roads	
Private and Secondary Roads	
Trails	
Street and Public Road Crossings	
Private Road Crossing	
Road Crossing at Grade	
" " under "	
" " overhead	
Crossing Gate	
Turnstile	
Cattle Guard	
Farm Gate	

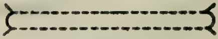
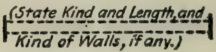
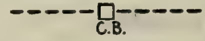
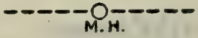
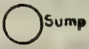
MINES.

Tunnel	
Shaft	
Test Opening	
Coal Outcrop	
Mine in Operation	

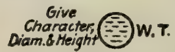
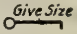
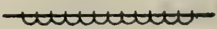
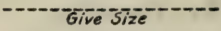
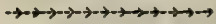
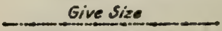
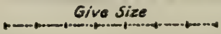
BRIDGES.

Girder	
Truss	
Trestle	
Signal Bridge	
Lift Span	
Bascule, Double Leaf	
Bascule, Single Leaf	
Draw Span	

CULVERTS, SEWERS, ETC.

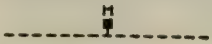
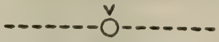
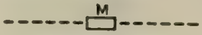
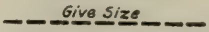
Masonry Arch or Flat Top Culvert	
Pipe or Wood Box Culvert or Drain	
Catch Basin	
Manhole	
Sump	

WATER SUPPLY AND PIPE LINES.

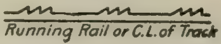
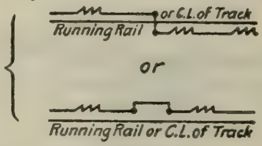
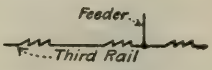
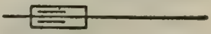
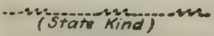
Water Tank	
Water Column	
Track Pan	
Company Water Pipe	
Other Water Pipe	
Steam or Gas	
Compressed Air	

WATER SUPPLY AND PIPE LINES.

(CONTINUED.)

Fire Hydrant	
Valve	
Riser	
Meter	
Sewer or Drain	

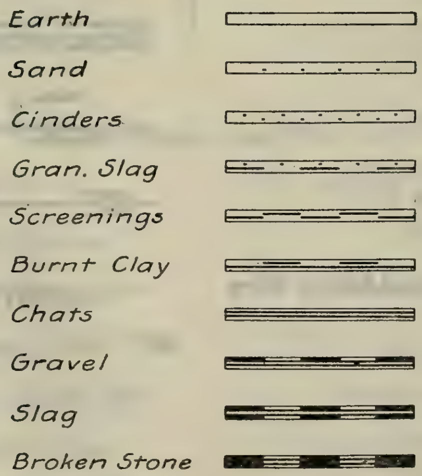
ELECTRIFIED LINES.

Third Rail	
Jumpers.	 or C.L. of Track Running Rail or Running Rail or C.L. of Track
Feeder	
Switch	
Overhead Rail or Wire	

Rail.

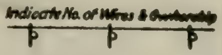
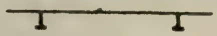
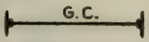
Give Weight in Lbs. per Yard.

Ballast.



Vol. 16, pp. 789. 1086. 1087.

MISCELLANEOUS.

Pole Wire Lines	
Rail Rest	
Gantry Crane	
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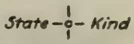
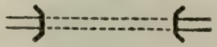
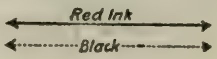
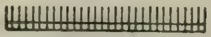
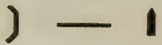
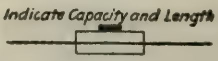
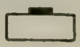
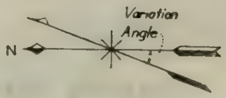
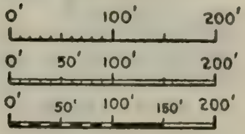
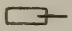
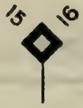
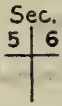
Other Lamps	
Railway Tunnel	
Dimension Lines	
Cribbing	
Abutment, Wall and Pier	
Track Scales	
Wagon Scales	
Mail Crane	
True and Magnetic Meridian	
Graphic Scales	
Boom Crane	
Gas Container	

SIGNS AND SIGNALS.

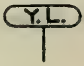
Mile Post



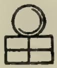
Section Post



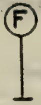
Yard Limits



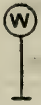
Highway Crossing Bell



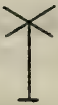
Flanger Sign



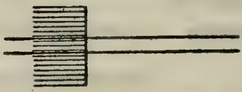
Whistle Post

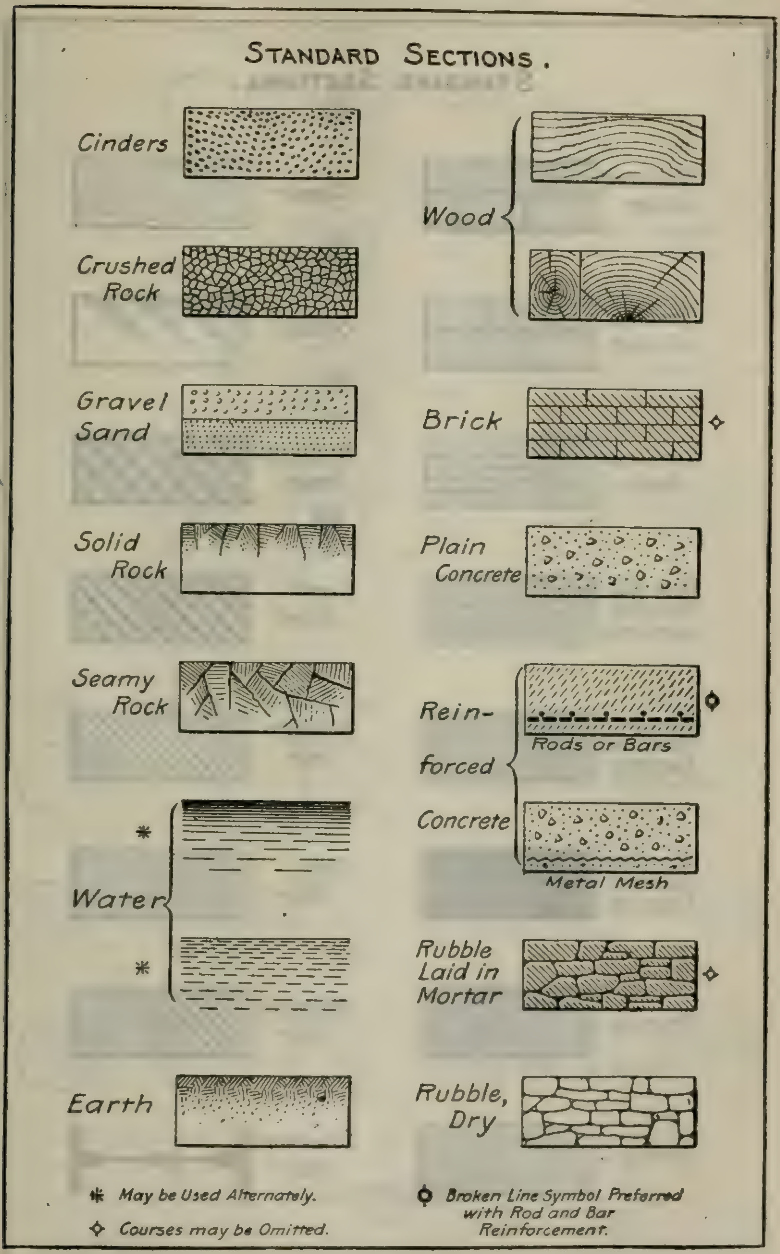


Crossing Sign

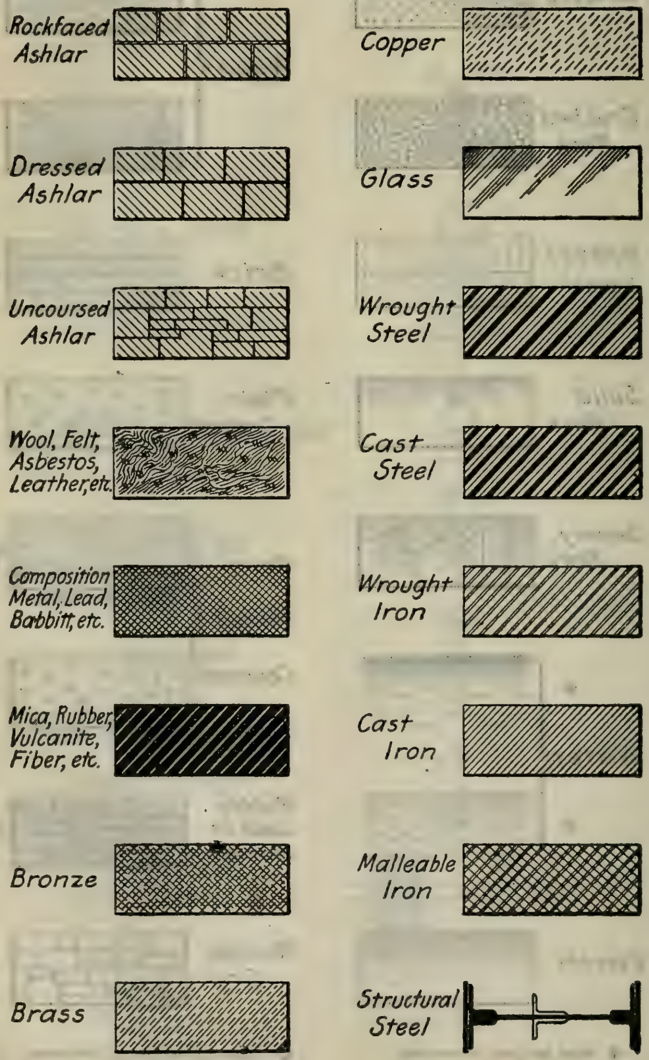


Tell-Tale



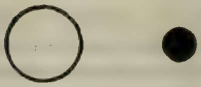

STANDARD SECTIONS.
Cinders
Crushed Rock
Gravel
Sand
Solid Rock
Seamy Rock
*
Water
*
Earth
Wood
Brick ◇
Plain Concrete
Rein-forced Concrete
Rods or Bars ⵔ
Metal Mesh
Rubble Laid in Mortar ◇
Rubble, Dry
* May be Used Alternately.
◇ Courses may be Omitted.
ⵔ Broken Line Symbol Preferred with Rod and Bar Reinforcement.

STANDARD SECTIONS.

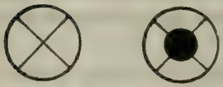


A—BRIDGE RIVETS

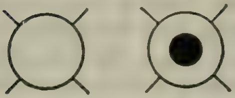
Shop. Field.



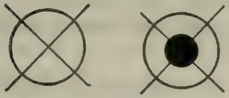
Two Full Heads.



Countersunk and chipped, far side.

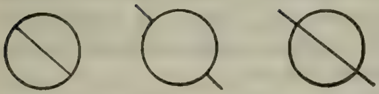


Countersunk and chipped, near side.

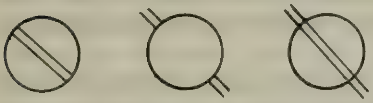


Countersunk and chipped, both sides.

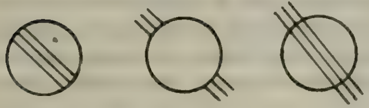
Far Side. Near Side. Both Sides.



Countersunk and not chipped.



Flattened to ¼-in. high for ½-in. and ⅝-in. rivets.



Flattened to ⅜-in. high for ¾-in., ⅞-in. and 1-in. rivets.

B—STRESSES

+ Tension.
— Compression.

[7]COST-KEEPING METHODS, STATISTICAL RECORDS, AND FORMS FOR ANALYZING EXPENDITURES FOR ASSISTANCE IN CONTROLLING EXPENDITURES

Cost-Keeping and Statistical Records, as applied to Railroad Maintenance, are so closely related that one may not well be considered without the other. For example, the cost of renewing ties per unit for a certain period of time is arrived at by cost-keeping but the result is a statistical record, and the statistical records of the number of ties placed, their cost, and the labor cost of renewing furnishes the information from which the cost is determined.

Figures obtained from Cost-Keeping and data shown by Statistical Records serve as a record of past performances, but become of greater value when proper application of them is made. Thus, to know the cost of renewing ties per tie is to establish a measuring stick for making comparisons of cost of future renewals with incentive to reduce the cost and establish new measuring sticks, and to know the length of life of ties in track and their costs lays the foundation for the study of the economic renewal of ties. In both instances the trend is toward efficiency and economy, the product of Cost-Keeping and Statistical Records, with the logical conclusion leading to the control of expenditures.

Forms for Analyzing Expenditures for Assistance in Controlling Expenditures are dependent upon Cost-Keeping and Statistical Records. In the following discussion these subjects are treated under their respective headings, but their close relationship should be kept mind.

Carriers are constantly striving to get the maximum worth of the maintenance dollar. They should be able to show that their expenses are efficiently and economically handled as a matter of sound business practice, but since the passage of the Transportation Act, 1920, it is essential that this information be readily available in handling matters with the Government pertaining to the recapture clause of this Act.

Fundamentals for these purposes require knowledge of the unit costs of maintenance, with comparisons of the costs of one period of time with another and of one location with another, and where several methods are in use, one method with another.

In the handling of these subjects, forms have been submitted as a guide for compiling the information and illustrating methods. It is not the recommendation that all the forms be printed for use, as it will be found that in some instances the information may be satisfactorily worked up on suitable cross-section paper in the drafting office, from which blueprints may be made, or the information may be typewritten as a form, with carbon copies, or for blueprinting.

A minimum of forms should be printed until an individual road has developed them to its satisfaction, after which it becomes a question of economy and convenience to have them printed or continue with having them prepared as above suggested.

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[7] Adopted, Vol. 26, 1925, pp. 776, 1429.

COST-KEEPING METHODS AND STATISTICAL RECORDS

For definitions of terms, see under "Definitions."

Essentials in Preparing, Assembling and Using Data

In preparing, assembling and making use of data for these purposes certain fundamentals must be observed.

It must first be determined in what unit the information is required, such as cost of renewing ties per tie, relaying rail per mile, painting bridges per ton of steel, maintaining roadway and track per equated track mile, etc. An analysis of the accounting and statistical routine should then be made to know that the information required is readily available, and if not in proper form it must be made to fit the requirements.

The field data are the foundation of Cost-Keeping and must be secured in sufficient detail for the purpose and be accurate. The assembling of the field data and the computation and compiling of costs should be performed in that office best prepared to handle, depending upon the road organization. Duplication of work should be avoided and best results will be obtained where it is handled by those most familiar with the character of the work.

Reports and the work connected therewith must be easily understood. Each step in securing and assembling the data must be simple and the transition from one step to the next must be logical and in progressive order, not involved or complicated.

Data must be economically assembled. Where possible, use should be made of information already at hand, and existing facilities should be adapted or expanded for its future accumulation. It should not cost more to get the records than they are worth or can be effected in savings brought about from their use.

Records must be for a purpose and the more specific and better defined the purpose the more valuable will be the result.

Reports and records must be periodic, not only as to the time interval they cover but as to the time they are available. With information readily available bad practices may be discovered as soon as they begin and promptly corrected, lagging performances checked and control of expenditures facilitated. The necessities of the case will determine the report frequency.

Information must be comparable. Data should be in sufficient detail to make the differences portrayed by the comparison intelligent, but too much detail is confusing and should be avoided. The number of comparisons which should be made to permit a fair criticism should be sufficient to give a true picture of the situation.

Data should be properly used. If not used, its preparation is a waste of money, and the compilation of such information should be discontinued at once. It should be possible from good records to predict results to locate a trouble definitely and to point out the possibility of further progress and improvement. In the last analysis, proper use and the savings effected thereby is the final gage of the value of any statistical record.

Application to Expenditures for Maintenance of Way and Structures

It is the purpose of the following discussion to make application of the foregoing to Expenditures for Maintenance of Way and Structures, and show how unit costs of individual items of work and costs of maintenance per equated track mile or similar unit may be determined, and submit forms as a guide for obtaining these results.

A study of this character should follow as nearly as possible the accounting routine laid down by the Interstate Commerce Commission, because the charges are assembled and reported by all carriers according to this schedule, and an analysis upon this basis can therefore be more satisfactorily made and the results will be comparable.

The Classification of Operating Expenses, as prescribed by the Interstate Commerce Commission, was not formulated to show directly unit costs of Maintenance and the limitations of the accounting in that respect control the kind of analysis of maintenance costs that can be made. Further consideration of these matters points out that this study may be resolved into three natural classifications. They are as follows and will be treated in their respective order:

(1) Maintenance Costs from Primary Accounts.
(2) Maintenance Costs from Sub-Primary Accounts.
(3) Maintenance Costs from Special Cost Study.

(1) MAINTENANCE COSTS FROM PRIMARY ACCOUNTS

By this is meant, as the term implies, that study of the costs of railroad maintenance that may be made of the charges to the Interstate Commerce Commission Primary Accounts as regularly assembled. These charges merely give total expenditures to the various accounts and are not prepared to show unit costs of performing any particular branch of the work, but as will now be shown these data may be easily compiled to show unit cost of Maintenance of Way and Structures per equated track mile or similar unit.

The Expenditures for Maintenance of Way and Structures are to be grouped under three headings—Roadway and Track, Bridges and Structures and Miscellaneous, with the appropriate primary accounts under each heading. Most of the primary accounts are made up of labor and material charges, so that it is not possible to obtain directly from the accounts a segregation of these two important items.

The unit established in this discussion is "Equated Track Mile," which is the ideal unit for cost data of this kind, as it is made up of weighted values of the different track items and is readily comparable. If a carrier prefers, "Track Mile Maintained" or similar unit may be substituted.

Form shown as Exhibit "A," is designed for assembling the data, all of which is readily available from the carrier's records, and securing such unit costs as can be obtained from this information. As previously pointed out, because of the limitations of the accounting, these unit costs will not show cost of individual work but will show unit cost of Roadway and Track, Bridges and Structures and Miscellaneous, and total cost of Maintenance per Equated Track Mile or similar unit.

From an inspection of the form it will be noted that Column (7) is the total of Account 202—Roadway Maintenance, and Account 220—Track Laying and Surfacing. These two accounts contain practically all the labor expended for Roadway and Track so that Column (8) will show very closely the labor cost of Roadway and Track per mile. Column (14) will show unit cost of Roadway and Track, Column (21) unit cost of Bridges and Structures and Column (27) unit cost of Miscellaneous Expenditures per mile.

Unit costs used especially for comparative purposes should have those items excluded that fluctuate considerably and tend to distort the results. Column (28) is the total of the three sub-divisions, Roadway and Track, Bridges and Structures and Miscellaneous, as shown on Exhibit "A," and Column (29) is the total cost per mile of what may be termed ordinary maintenance or that maintenance which is under control.

Additional items of Maintenance which may fluctuate greatly and are beyond the control of the official in direct charge are:

Removing Snow, Ice and Sand	Column (30)
Assessments for Public Improvements	Column (31)
Maintaining Joint Tracks, Yards and other Facilities—Debit	Column (32)
Maintaining Joint Tracks, Yards and Other Facilities—Credit	Column (33)
Charge to Maintenance from A.F.E. Work	Column (34)
Cost of Floods, Etc.	Column (35)
Other Miscellaneous Charges	Column (36)

The grand total cost of any work should include all extraordinary items. The charges above shown, Columns (30) to (36), inclusive, are added to the total cost of Ordinary Maintenance, Column (28), to make Grand Total, Column (38), and the cost per mile of this total is given in Column (39).

This form is for use on a division of road, or the information of several divisions may be assembled for a major division, and this information assembled for the entire road. The data on this form is to be shown monthly for the current year, with comparison with the same months of the two preceding years, with record of charges and costs for the current year, when concluded, with comparison with sufficient number of preceding years to give a true picture of the relative costs.

Summarized, the form will show comparison of expenditures of the principal items of Maintenance by months and by years, and will also show the following unit costs per equated track mile for the same periods.

Labor Cost of Maintaining Roadway and Track (Accounts 202 and 220).
Total Cost of Maintaining Roadway and Track.
Total Cost of Maintaining Buildings and Structures.
Total Cost of Miscellaneous.
Total Cost of Ordinary Maintenance of Way and Structures.
Grand Total Cost of Maintenance of Way and Structures.

The form is submitted as a guide for cost study. It is easily seen that it may be further consolidated to show less detail, or enlarged to show more detail. Used as outlined it will be found to be of value in analyzing expenditures and costs and subsequently controlling expenditures.

(2) MAINTENANCE COSTS FROM SUB-PRIMARY ACCOUNTS

By this term is meant that study of the costs of railroad maintenance that may be made of any branch of the work by the sub-division of the primary accounts in such manner that the charges are allocated to the subject under consideration so that unit costs for that class of work may be determined. This is necessary because it has been found in making a study of Cost-Keeping, as applied to Railroad Maintenance, that the charges to the Classification of Accounts as now prescribed by the Interstate Commerce Commission do not furnish the information for an analysis of the unit costs of maintenance of roadbed, track and structures.

Thus Account No. 220—Tracklaying and Surfacing, includes cost of renewing ties, rail, frogs, switches and crossings, lining, surfacing and gaging track, re-ballasting and other items. This and other accounts, both labor and material, need further classifying before costs of doing certain work can be properly determined.

This may be accomplished by assigning sub-account to the several classes of work, as:

220-A—Renewing Ballast.
220-B—Renewing Ties.
220-C—Renewing Rail.
220-D—Renewing Frogs, Switches, Crossings, etc.

The sub-division of primary accounts is recommended as good practice, but it must be understood that it involves some additional expense, which expense is justified if the information thus obtained is used in determining and comparing unit costs, and has for its ultimate purpose the economy of maintenance. The refinement to which this may be carried is not altogether unlimited and should be determined by the value that may be obtained from such an analysis, compared with the cost of securing the information.

Exhibit A has been discussed as the base form for making cost studies under classification "Maintenance Costs from Primary Accounts," and it may also be used as the base for making cost studies of individual items of Maintenance of a division or road, combined with all the other items of Maintenance, so as to secure unit costs of individual work and as a final result obtain the cost of Maintenance of Way and Structures per equated track mile or similar unit.

Exhibit B has been designed to show the application of this method to Roadway and Track. Expenditures are segregated to Labor and Material. Labor is further segregated to the main items of work, such as re-ballasting, renewing ties, renewing rail, ditching, care of roadbed, patrolling and watching, etc., with appropriate units for each class of work and with quantities of materials used, thus giving the information for determining unit costs. Expenditures for material are segregated to the appropriate account numbers.

The form as submitted will show comparison of expenditures to the segregated items of Maintenance by months and by years, and will also show the following unit costs for the same periods:

Labor Cost of Cleaning Stone Ballast....	Per Track Mile
Labor Cost of Ballasting with Stone.....	Per Cubic Yard
Labor Cost of Ballasting with All Other Ballast	Per Cubic Yard
Labor Cost of Renewing Main Track Ties	Per Tie
Labor Cost of Renewing Side Track Ties.	Per Tie
Labor Cost of Renewing Switch Ties.....	Per M. Ft. B. M.
Labor Cost of Respacing Ties...........	Per Track Mile

Exhibit A

NORTH & SOUTH R.R.

MAINTENANCE OF WAY AND STRUCTURES

STATEMENT OF EXPENDITURES AND COSTS

	TRACK MILES MAINTAINED			ROADWAY & TRACK										BRIDGES & STRUCTURES							MISCELLANEOUS						TOTAL ORDINARY MAINTENANCE		EXTRAORDINARY EXPENDITURES								GRAND TOTAL	
				LABOR MATERIAL & MISCELLANEOUS										LABOR, MATERIAL & MISCELLANEOUS							LABOR, MATERIAL & MISCELLANEOUS										Maintaining Jt Tks & O F							
[illegible]	[illegible]	[illegible]	[illegible]	Acct 202	Acct 220	Total Accts 202 & 220	Cost per Mile	Acct 212	Acct 214	Acct 216	Acct 218	Grand Total	Cost per Mile	Bridges Acct 208	Buildings Acct 227 to 239 inc 251 253 255 265	Docks & Wharves Acct 241 243	Tunnel Over & Under Grade Xings Accts 224 225	Fences Accts 221 223	Total	Cost per Mile	Signals & Inter-locker Acct 249	Teleph Teleg & Power Lines Accts 247 257 259 261	Misc Accts 267 269 271 274 275 276 277	Acct 201	Total	Cost per Mile	Total	Cost per Mile	Removing Snow Ice & Sand Acct 272	Assts for Public Imp Acct 273	Debit Acct 278	Credit Acct 279	Charges to MofW&S from AFE Work	Cost of Floods etc	Other Misc Charges	Total	Total	Cost per Mile
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39

Exhibit B

NORTH & SOUTH R.R.

MAINTENANCE OF WAY AND STRUCTURES

STATEMENT OF EXPENDITURES AND COST

ROADWAY AND TRACK

	TRACK MILES MAINTAINED			Av Hourly Rate of Pay Track Forces ex Foremen	LABOR																																														MATERIAL						TOTAL	
					BALLAST									TIES												RAIL						Applying Other Track Material	TOTAL TRACK RENEWALS		TRACK MAINTENANCE Line and Surface Gauging Acct 220 E				Ditching Acct 202-A		Care of Roadbed Acct 202 B		General Cleaning Acct 202 C		Patrolling and Watching Acct 202-D		TOTAL				TRACK RENEWALS							
					Cleaning Stone Ballast			Stone			Other Ballast			Main			Side			Switch			Respacing			New			Repair						Main		Side										Labor		Cost Equated Track Mile						TOTAL TRACK RENEWALS			
[illegible]	Miles of Main Tk	Miles of Side Tk	Equated Track Miles	Cts	Miles	Labor Acct 220-A $	Cost per Mile $	Cu Yds	Labor Acct 218 & 220-A $	Cost per Cu Yd $	Cu Yds	Labor Acct 218 & 220 A $	Cost per Cu Yd $	Number	Labor Acct 220 B $	Cost per Tie $	Number	Labor Acct 220 B $	Cost per Tie $	MBM	Labor Acct 220 B $	Cost per MBM $	Miles	Labor Acct 220 B $	Cost per Mile $	Gross Tons	Labor Acct 220 C $	Cost per Gross Ton $	Gross Tons	Labor Acct 220 C $	Cost per Gross Ton $	Labor Acct 220-D $	Labor $	Cost per Eq'td Trk Mile $	Labor $	Cost per Mile Main $	Labor $	Cost per Mile Side $	Labor $	Cost per Mile of Ditch $	Labor $	Cost per Track Mile $	Labor $	Cost per Track Mile $	Labor $	Cost per Track Mile $	Man Hours inc Foremen	Money $	Man Hours	Money $	Ties Cross & Switch Acct 212 $	Rails New & Repair Acct 214 $	Other Track Material Acct 216 $	Ballast Acct 218 $	Material $	Cost per Eq'td Trk Mile $	LABOR TRAIN SERVICE MATERIAL $	Cost per Eq'td Track Mile $
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59

Labor Cost of Renewing with New Rail	Per Gross Ton
Labor Cost of Renewing with Repair Rail	Per Gross Ton
Total Labor Cost of Track Renewals	Per Equated Track Mile
Labor Cost of Lining, Surfacing and Gaging	Per Track Mile
Labor Cost of Ditching	Per Mile of Ditch
Labor Cost of Care of Roadbed	Per Track Mile
Labor Cost of General Cleaning	Per Track Mile
Labor Cost of Patrolling and Watching	Per Track Mile
Total Labor Cost of Roadway and Track (Man Hours)	Per Equated Track Mile
Total Labor Cost of Roadway and Track (Dollars)	Per Equated Track Mile
Total Material Cost of Roadway and Track	Per Equated Track Mile
Total Labor, Train Service and Material Cost of Roadway and Track	Per Equated Track Mile

Column (58) of Exhibit B will show the total charge to Roadway and Track, and is identical with the total charge to Roadway and Track, Column (13), of Exhibit A, and these totals will be the summation of charges to the several accounts as shown by the carrier's records.

Normally the expenditures for Roadway and Track will approximate 60 per cent to 70 per cent of Total Expenditures for Maintenance of Way and Structures, the balance being divided between charges to Buildings and Structures, Miscellaneous and Extraordinary Expenditures as shown on Exhibit A.

Many of the items comprising these last named three sub-divisions do not lend themselves readily to unit cost analysis and most of the remaining do so but indifferently. It would seem, therefore, that, except for such items as might be the subject of special cost study as an individual road would determine, the most available and most satisfactory comparison is that of money expenditure for similar periods of time as shown on Exhibit A.

Exhibit B may, therefore, be concluded with Column (59) as a form for Analyzing Expenditures for Roadway and Track, or supplemented with Columns (15) to (39), inclusive of Exhibit A, thus making a complete Exhibit of Expenditures for Maintenance of Way and Structures. If the combined forms should be thought unwieldy, this objection can be met by preparing two forms, the first to be Exhibit B, as submitted, showing in detail the Expenditure for Roadway and Track, the second to be similar to Exhibit A with Columns (5) to (12), inclusive, under heading Roadway and Track omitted and two Columns, (13) and (14), retained showing Total Cost and Cost per Mile, which information would be taken directly from Columns (58) and (59), respectively, of Exhibit B.

Like Exhibit A this form is intended as a guide for cost study only, and may be consolidated to show less detail or enlarged to show more detail, as the road making use of it may determine.

In Cost-Keeping analyses the generally accepted unit of value is the dollar. The principal objection that may be raised to the use of this unit is the difference in the wage rate per hour in different localities even on the same road for the same class of work. The best unit of measure for labor is undoubtedly the hour, and in studies of efficiency for comparing work performed hours worked instead of dollars expended would doubtless prove the more satisfactory unit. In studies of this nature, however, it can not be easily combined with money values of material and the dollar unit should be used.

(3) MAINTENANCE COSTS FROM SPECIAL COST STUDY

Maintenance cost studies (1) and (2) have to do with total unit costs of work performed, such as Expenditures for Roadway and Track per equated track mile, total cost of renewing ties per tie, relaying rail per gross ton, etc., with the ultimate object of economy of maintenance. Any specific work is made up of a number of operations repeated for each unit of installation; to be certain that the cost of doing the work as a whole is being economically performed the principal individual steps in carrying on the work should be analyzed and costs determined and compared. Without repetition it will be understood that the routine of accounting and gathering of the statistical information, as previously outlined, for handling of special cost studies has already been provided.

There is a large field of cost study in this line, but it is not practical or necessary to give examples of all. Typical subjects have been selected and practically the same method of handling may easily be applied to other subjects. The subjects considered are as follows:

Cost of Renewing Cross-Ties—Exhibit 1

This exhibit will show material cost of tie, train service expense in handling, and detail of labor expense in making the tie renewal with total cost per tie.

This information will also be shown graphically on the Exhibit with comparison of similar data for preceding years, from which the comparative costs and the trend are readily noted.

The cost of renewing switch ties and bridge ties may be shown in like manner.

Cost of Renewing Rail—Exhibit 2

A number of operations are involved in the re-laying of rail and the cost of the work will depend to some extent upon how it is handled, that is, if it is laid under traffic, by hand or by machine.

This Exhibit is designed to show this information, with cost per unit and cost per mile, segregated to labor, work train service and material and combined for total expense.

The data thus obtained should be of much value in showing the cost of any one project and for making study of comparison of cost of similar work done under other conditions and with other methods.

Cost of Painting Bridges per Ton of Steel and per Square Foot of Surface Area—Exhibit 3

One of the principal items of the cost of maintaining steel bridges is cost of painting. This Exhibit is designed to be used for individual bridges, but with slight modifications it may be used for all bridges of a type or for all bridges of a division or system.

It will be found useful in comparing efficiency of painting gangs on the same division or one division with another, and in making comparison of the merits of different brands of paint.

Similar forms may be prepared to record cost of painting buildings and other maintenance costs where the work is in sufficient volume to justify the record.

Cost of Maintenance and Operating Coaling Stations—Exhibit 4

This Exhibit is designed to give comparative data of the cost of maintenance and of operation of Coaling Stations by years and by types of plant. This form may be subject to criticism because of the inclusion of cost of operation, but it has been prepared in this manner because there are roads where the management of operation as well as of maintenance rests with the Engineering Department, and also where it is an Engineering duty to investigate cost of operation and to assist in the selection of the proper type of station.

The cost of maintaining and operating water stations, cinder pits, etc., may be obtained in like manner.

STATISTICAL RECORDS

Statistical Records of Maintenance of Way and Structures cover a large variety of subjects, and include such items as number of ties, renewed, tons of rail laid, cubic yards of ballast placed, man hours worked, etc., and also include costs of work performed either in unit assigned or in total. Exhibits A and B, while developed for the purpose of illustrating Cost-Keeping Methods, are none the less Statistical Records which show periodical expenditures to the several sub-divisions of maintenance and unit costs of certain items.

Some typical forms for recording statistics in connection with railroad maintenance and for use in the study of maintenance costs are presented herewith:

Hourly Rates of Pay of Trackmen—Exhibit 5

This chart provides for a graphic representation of hourly rates of pay and also the length of the working day. Prior to 1917 there had been but little variation from year to year in these items, but subsequently rates of pay were increased more than 100 per cent and the working day generally reduced from ten hours to eight. In comparing expenditures per unit of work from year to year and making a study of the same, it is necessary that the information as to rates of pay and hours of labor be readily available that a true comparison of the cost per unit may be had.

Hourly rates of pay of other classes of labor may be charted on similar forms.

Average Cost of Ties and Rail—Exhibits 6 and 7

These two Exhibits show in graphic form a method of recording the average cost of cross-ties and of rail. As additional information, on Exhibit 7 is shown average cost of relayer and scrap rail.

Comparison of Tie Renewals—Exhibit 8

This chart shows a comparison of tie renewals, estimated and actual, from the year 1900 to and including the current year. The chart also shows number of ties in track on sub-division, division or road, with annual renewsls to be made, based on varying lengths of life of ties from five (5) to twenty (20) years.

The actual average life of ties in track is also shown. The method used for determining this for any year is to ascertain the number of prior years required to accumulate total renewals equal to the average number of ties in track on the section of track under consideration.

This chart will show the trend of longer life of tie, due to greater use of treated ties and tie plates.

Rail in Track and Rail Renewals—Exhibit 9

This chart shows in statement form rail in track—both gross tons and track miles, also rail renewals in gross tones, track miles and in track miles per cent.

Renewals in track miles is shown graphically. This unit is chosen rather than gross tons, as it is believed it will more accurately represent comparison by years.

If gross tons is used as the unit, the renewals with heavier section rail will distort the graphical yearly comparison. The same thing is true, of course, with track miles as the unit in case of mileage added to the track section under consideration, but the unit used should be the more constant.

Graphical Comparison of Hours of Labor Worked—Exhibits 10, 11 and 12

Exhibits 10 and 11 show total labor worked in the several sub-divisions of Maintenance of Way and Structures; the former gives comparison by months for the three preceding years, thus showing the seasonal variation, while the latter gives comparisons by years.

Over a period of years, the sub-divisions in Exhibit 11 may show a decided trend. Thus, due to increased use of signals and electrical equipment, the hours of labor will show a rising trend, while permanent bridges, more substantial buildings, etc., should reduce hours of labor and show a decreasing trend in that sub-division.

Exhibit 12 gives comparison of total hours of labor worked maintaining roadbed and track per road mile, track mile and equated mile.

If the amount of work to be done yearly were constant, this form would show the relative efficiency of labor and supervision. Allowance, however, may be made for this variation and the chart should be of value in assisting in the control of expenditures.

Graphical Comparison of Expenditures—Exhibits 13, 14 and 15

Exhibit 13 shows comparison of Total Expenditures by years for Maintenance of Way and Structures, and sub-divided into Roadway and Track, Bridges and Buildings, Signals and Electrical and "All Others."

Exhibit 14 gives comparison of total cost of maintaining roadbed and track per road mile, track mile and equated track mile.

These two forms are the same as Exhibits 11 and 12, except that while expenditures are charted on these, hours of labor are charted on them.

Exhibit 15 shows comparison by years for expenditures per 1,000,000 Gross and Net Ton Mile.

FORMS FOR ANALYZING EXPENDITURES FOR ASSISTANCE IN CONTROLLING EXPENDITURES

Control of Expenditures

Control of Expenditures is the regulation of expenses and in its larger sense is a function of management.

Management has to do with service to the public, upkeep and betterment of the property and provisions for meeting tolls for use of capital. The cost of capital is fixed and the cost of service to the public is variable only to the extent that business fluctuates or economies in transportation are effected, as the service must be performed and its character should not be deteriorated.

Control by Fixed Amounts

The amounts to be expended for upkeep and betterment of property are first established through the medium of a program or budget determined by the condition of the several units of the property, the estimated requirements of the property for the succeeding period or periods, based to some extent upon experience of past similar expenditures, and predicated upon the anticipated revenue being sufficient to meet the estimated expenses.

When revenues are not produced as anticipated the management, mindful of its duty to the public for service and to the lenders of capital for their charges, is confronted with the problem of reducing the expenditures to meet the necessities of the case. The practical method of doing this is to allot stipulated amounts for expenditures for certain divisions of work for designated periods, with the responsibility of the proper distribution of the allotment left to those more directly in charge.

Two Exhibits are herewith presented showing Control of Expenditures by Fixed Amounts.

Estimated Expenditures of Maintenance of Way and Structures for Current Month of Current Year, Compared with the Same Month of the Three Previous Years—Exhibit 16

Estimate is prepared by Interstate Commerce Commission Accounts and compared with the Actual Expenditures for the three previous years, as shown on the form. The management may restrict the proposed expenditures to a certain sum, to the average expenditures of the last three years or to last year's expenditures. If the estimate exceeds the allowance, reductions are made in those accounts where the work is the least urgent.

When the actual expenditures for the month estimated have been received they are entered on the form for checking accuracy of the estimate with the actual and for assistance in preparing next month's estimate.

Totals for period to date furnish check on actual and estimated expenditures of the current year.

Estimated Expenditures of Maintenance of Way and Structures for Current Month of Current Year—Exhibit 17

The general plan of dealing with expense of the Maintenance of Way Department is that the Engineer, after conferring with the Supervisors, prepares and submits to the Superintendent a statement on this Exhibit on which is shown the force to be worked the coming month, by Supervisor's districts, and on the same form is shown the force worked in the corresponding month of the preceding year. Under the title of expense is shown, by accounting items, the estimated total expenditures, including both labor and material; also such portions of expense which may be chargeable to Additions and Betterments, and this likewise is compared with the same period of the previous year. This statement is accompanied by a very full and complete detail showing the general plan to be followed during the succeeding month. Quantities and values of various kinds of material to be used are included on this detailed statement and this information, after being approved by the Superintendent, is furnished in triplicate through the General Superintendent's office, to the Engineer Maintenance of Way on the 20th of the month. The Engineer Maintenance of Way then prepares his recommendations and submits them to the General Manager on the 24th of the month for authorization.

As soon as the Engineer Maintenance of Way has been advised what he will be permitted to expend in this particular month, a conference is held at the office of the Engineer Maintenance of Way, which meeting is attended by the General Superintendent and District Engineer of the grand district, and all of the Superintendents and Engineers within such grand district, at which time a general discussion is conducted in which Division Officers are encouraged to express freely their views and recommendations covering the work at hand. At this meeting the Engineer Maintenance of Way and General Superintendent decide upon the expenses, which, in their judgment, are necessary and advisable. In case all the expenditure requested has not been authorized, the amount of money to be spent is redistributed between the Bridge, Building, Track, Water Service and other departments, where most needed.

The value of these meetings and the discussion of the work are manifold:

> It enables the General Superintendent and District Engineer to obtain information bearing upon the condition on each Division that could not be easily obtained in any other way, and provides for the monthly appropriation to be expended to the best advantage.
>
> It provides a means for a better control of practice on the various Districts and Divisions, and may prevent the use of extravagant methods on lines where the character or quantity of business would not justify as high a class of railroad as on more important lines.
>
> It assists in formulating plans for carrying on the work in a quick and thorough manner, which could not be so well accomplished by correspondence, and minimizes to a very great extent letter writing and the making of reports.
>
> It is of great value to the Division Officers in encouraging them to express their views and opinions about this very important feature of the work. It strengthens them in their responsibility

towards the proper maintenance of their territories, makes them feel that their views are worth considering, and brings them in closer contact with the General Officers.

The monthly allotment decided upon is given the Division Officers at this expense conference, and the Superintendent and Engineers on reaching their headquarters call a conference of their Supervisors. The expenditures are divided in an equitable manner, each Supervisor being given a definite allowance of men and material covering the thirty-day period.

The Supervisors in turn advise their respective foremen of their allotment of men and material for the month, and in order to regulate the appropriation, the foremen daily furnish their Supervisors with a statement of the amount of force and material used on the work under their jurisdiction. The Supervisors consolidate these reports and forward them to the Engineer, with the result that the Division Officers have immediate knowledge of total expenditures to date.

When extraordinary conditions arise during the month, such as washouts, wrecks, snowstorms, and the like, the practice is to have the Division Superintendents, through their General Superintendent, advise the Engineer Maintenance of Way just how much additional allotment is required. If this extraordinary expense is found extensive, the Engineer Maintenance of Way orders retrenchments on various Divisions of the System in order to offset the extraordinary charges.

After the accounts are closed for the month, the Engineer prepares a statement on this Exhibit showing the actual expenses and the allotment figures, together with a detailed explanation of the increases and decreases in each account.

Control Through Economy of Maintenance

In the discussion under Cost-Keeping Methods and Statistical Records, forms have been prepared by which unit costs of maintenance may be obtained. These Exhibits were designed for Cost-Keeping purposes, but the relationship of these subjects is such that the information available from these forms may be readily used for analyzing expenses for assistance in controlling expenditures.

Thus Exhibit A was designed for studying maintenance costs from data available from the carrier's primary accounts, and the summary statement on page 760 shows the information that may be compiled and made available for analysis.

In the study under Cost-Keeping Methods it was found that by making appropriate sub-divisions of the primary accounts a larger number of unit costs could be secured, and Exhibit B was designed for that purpose. The summary statement on page 761 shows the information that may be compiled and made available for analysis with the use of that form.

It was further found from the study of Cost-Keeping Methods that additional cost data could be obtained by cost study of certain items in addition to that shown from Exhibits A and B, which is discussed on page 764 under caption of "Maintenance Costs from Special Cost Study," and forms were likewise designed for these subjects.

The forms above listed will be found suitable for analyzing expenditures for control of expenditures and are recommended for that purpose.

Summary

(1) The Classification of Operating Expenses, as prescribed by the Interstate Commerce Commission, is not formulated to show directly unit costs of any item of Maintenance of Way and Structures, but these data may be compiled to show unit cost of Maintenance per Equated Track Mile or similar unit.

(2) Unit costs of the main items of Maintenance, particularly those pertaining to Roadway and Track, may be determined by sub-division of the primary accounts in such manner that the charges are allocated to those items. The sub-division of primary accounts involves some additional expense, which is well justified when the information thus obtained is used in determining and comparing unit costs, and is recommended as good practice.

(3) Analyses of the costs of the details of any item of Maintenance can not be made from the primary accounts or sub-divisions of primary accounts, but they may be obtained in the manner desired through special cost study of that subject.

(4) Cost-Keeping and Statistical Records, applied to Expenditures for Maintenance of Way and Structures, as indicated in this report, is a practical matter. Through their application expenses may be analyzed, economies of maintenance brought about and control of expenditures facilitated.

Exhibit 1

NORTH & SOUTH R.R.

COST OF RENEWING CROSS TIES

FOR YEAR.......

WITH COMPARISON FROM YEAR 1910 TO DATE

............DIVISION

	TOTAL COST	NO OF TIES	COST PER TIE
MATERIAL			
COST OF TIES DELIVERED TO TREATING PLANT			
COST OF TREATMENT			
FREIGHT TO DIVISION STORE YARD	____	____	____
TOTAL COST AT DIVISION STORE YARD			
TRAIN SERVICE			
DISTRIBUTING NEW TIES			
DISPOSING OF TIES RELEASED	____	____	____
TOTAL TRAIN SERVICE			
LABOR			
UNLOADING AND DISTRIBUTING NEW TIES			
DISPOSING OF TIES RELEASED			
REMOVING OLD TIES FROM TRACK			
PLACING NEW TIES IN TRACK			
TAMPING UP NEW TIES	____	____	____
TOTAL LABOR			
GRAND TOTAL	____	____	____

CLASSIFICATION OF BALLAST IN TRACK...

CLASSIFICATION OF NEW TIES...

NOTE: DESIGNATE KIND OF BALLAST IN TRACK, AS. STONE, GRAVEL, CINDERS, ETC. AND KIND OF TIES USED FOR RENEWALS AS CREOSOTED, ZINC TREATED, WHITE OAK, ETC.

IF IN THE TERRITORY UNDER ANALYSIS MORE THAN ONE KIND OF BALLAST IS IN TRACK OR DIFFERENT KINDS OF TIES ARE USED PREPARE SEPARATE FORMS FOR EACH. IF THIS IS NOT PRACTICABLE INDICATE BY APPROXIMATE PERCENTAGES.

RECORD ANY UNUSUAL EXPENDITURE IN RENEWING TIES THAT MAY DISTORT THE COST. AS RENEWING TIES IN INTERIOR TRACKS OF THREE OR MORE MAIN LINE TRACKS, ETC.

CHART OF COST OF RENEWALS PER TIE

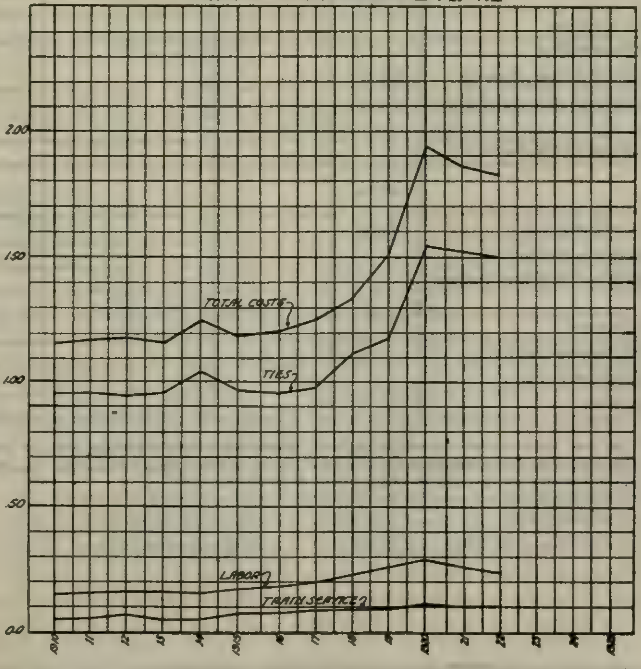


Exhibit 2

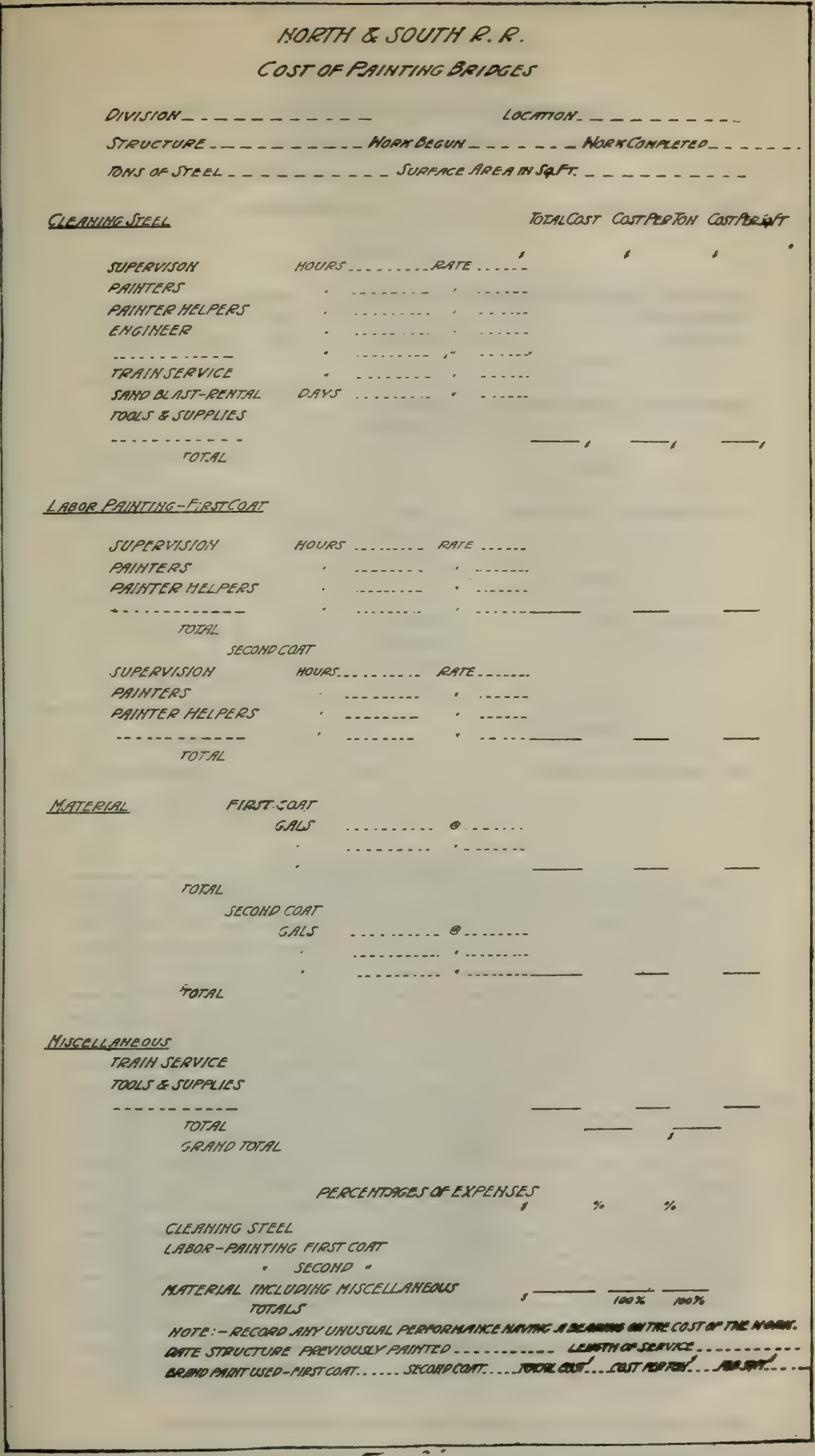
NORTH & SOUTH R.R.
COST OF RE-LAYING RAIL

Division.. A.F.E...
Line.. Work Begun.................Completed...................
M.P..........to M.P...........M.P.........to M.P......... Hourly Rate Trackmen...
Valuation Section...................................... Salary of Foreman...
Total No. of Miles Laid................................. Salary of Assistant Foreman..................................
Weight of Rail Laid.........New or Relayer................ Salary of Timekeeper..
Weight of Rail Released........Relayer or Scrap........... Salary of Machine Operator...................................
Rail Laid Under Traffic.................................. Average No. of Men per Day....................................
Hand or Machine Laid..................................... Average Labor Cost per Day....................................
Kind of Machine... No. of Days Worked..........Hours Worked Per Day.........

ITEM	UNIT 1	NUMBER OF UNITS 2	TOTAL COST 3	COST PER UNIT 4	MILES 5	COST PER MILE 6
LABOR						
1 Loading and Distributing Material	Trk. Ft.					
2 Laying Rail (Incl. Flag. Plg. Ties)	Trk. Ft.					
3 Adzing Ties	Number					
4 Spacing Ties	Number					
5 Applying Tie Plates	Number					
6 Applying Rail Anchors	Number					
7 Lining and Surfacing	Trk. Ft.					
8 Placing Turnouts	Number					
9 Placing Interlocked Switches	Number					
10 Restoring Highway Crossings	Number					
11 Placing R.R. Crossings	Number					
12 Bonding Track and Switches	Trk. Ft.					
13 Curving Rail	Rail. Ft.					
14 Loading and Unloading Released Material	Trk. Ft.					
15 Delay from Trains. Number ~	Hours					
16 Delay from Other Causes	Hours					
17						
18 TOTAL LABOR						
WORK TRAIN SERVICE						
19 Loading and Distributing Material	Trk. Ft.					
20 Loading and Unloading Released Material	Trk. Ft.					
21 Other Work						
22 TOTAL WORK TRAIN SERVICE						
MATERIAL 23 Rail-Applied	Gr. Ton					
24 Rail-Credit for Rail Released	Gr. Ton					
25 Other Track Material-Applied						
26 Other Track Material-Credit for Material Released						
27						
28 TOTAL MATERIAL						
29 TOOLS AND MISCELLANEOUS SUPPLIES						
30 ENGINEERING AND SUPERVISION						
31 GRAND TOTAL						

NOTE: Indicate Total number of trains causing delay. The cost of delay to be included in total and unit costs of the work affected, but the amount chargeable to each item should be shown under remarks. If additional space is needed use separate sheet and attach to this form.

REMARKS...
....
....
....
....



NORTH & SOUTH R. R.

COST OF PAINTING BRIDGES

DIVISION .... LOCATION ....

STRUCTURE .... WORK BEGUN .... WORK COMPLETED ....

TONS OF STEEL .... SURFACE AREA IN SQ.FT. ....

					TOTAL COST	COST PER TON	COST PER SQ FT
CLEANING STEEL					$	$	$
SUPERVISON	HOURS	....	RATE	......			
PAINTERS	"	....	"	......			
PAINTER HELPERS	"	....	"	......			
ENGINEER	"	....	"	......			
....	"	....	"	......			
TRAIN SERVICE	"	....	"	......			
SAND BLAST-RENTAL	DAYS	....	"	......			
TOOLS & SUPPLIES							
....							
TOTAL					$	$	$
LABOR PAINTING-FIRST COAT							
SUPERVISION	HOURS	....	RATE	......			
PAINTERS	"	....	"	......			
PAINTER HELPERS	"	....	"	......			
....	"	....	"	......			
TOTAL							
SECOND COAT							
SUPERVISION	HOURS	....	RATE	......			
PAINTERS	"	....	"	......			
PAINTER HELPERS	"	....	"	......			
....	"	....	"	......			
TOTAL							
MATERIAL	FIRST COAT						
	GALS	....	@	......			
	"	....	"	......			
	"						
TOTAL							
	SECOND COAT						
	GALS	....	@	......			
	"	....	"	......			
	"	....	"	......			
TOTAL							
MISCELLANEOUS							
TRAIN SERVICE							
TOOLS & SUPPLIES							
....							
TOTAL							
GRAND TOTAL						$	

PERCENTAGES OF EXPENSES

	$	%	%
CLEANING STEEL			
LABOR-PAINTING FIRST COAT			
" SECOND "			
MATERIAL INCLUDING MISCELLANEOUS			
TOTALS	$	100%	100%

NOTE:-RECORD ANY UNUSUAL PERFORMANCE HAVING A BEARING ON THE COST OF THE WORK.

DATE STRUCTURE PREVIOUSLY PAINTED .... LENGTH OF SERVICE ....

BRAND PAINT USED-FIRST COAT...... SECOND COAT.... TOTAL COST... COST PER TON... PER SQ FT....

NORTH & SOUTH R.R.
ANALYSIS OF COST OF
MAINTAINING AND OPERATING COALING STATIONS
FOR YEAR...... WITH COMPARISON FROM YEAR...... TO DATE
DIVISION..........
TYPE OF STATION.................................... LOCATION..........

ANALYIS OF COST

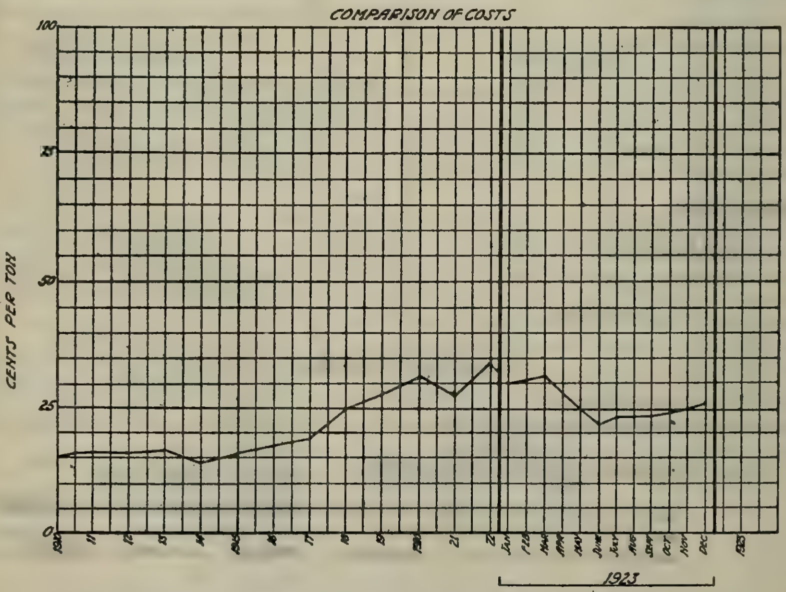
INTEREST ON INVESTMENT–ORIGINAL COST $ @ % $
DEPRECIATION " " @ %
INSURANCE INSURED VALUE @ % ______
TOTAL

MAINTENANCE POWER EQUIPMENT – LABOR
" " –MATERIAL
" " -------- ______
TOTAL

MAINTENANCE OF STRUCTURE –LABOR
" " –MATERIAL
" " -------- ______
TOTAL

COST OF OPERATING LABOR
" " " MATERIAL
" " " POWER
" " " -------- ______
TOTAL ______
GRAND TOTAL

COAL HANDLED FOR PERIOD........................TONS COST PER TON $.........



NOTE: RECORD ANY UNUSUAL EXPENDITURE HAVING A BEARING ON THE COSTS

Exhibit 5

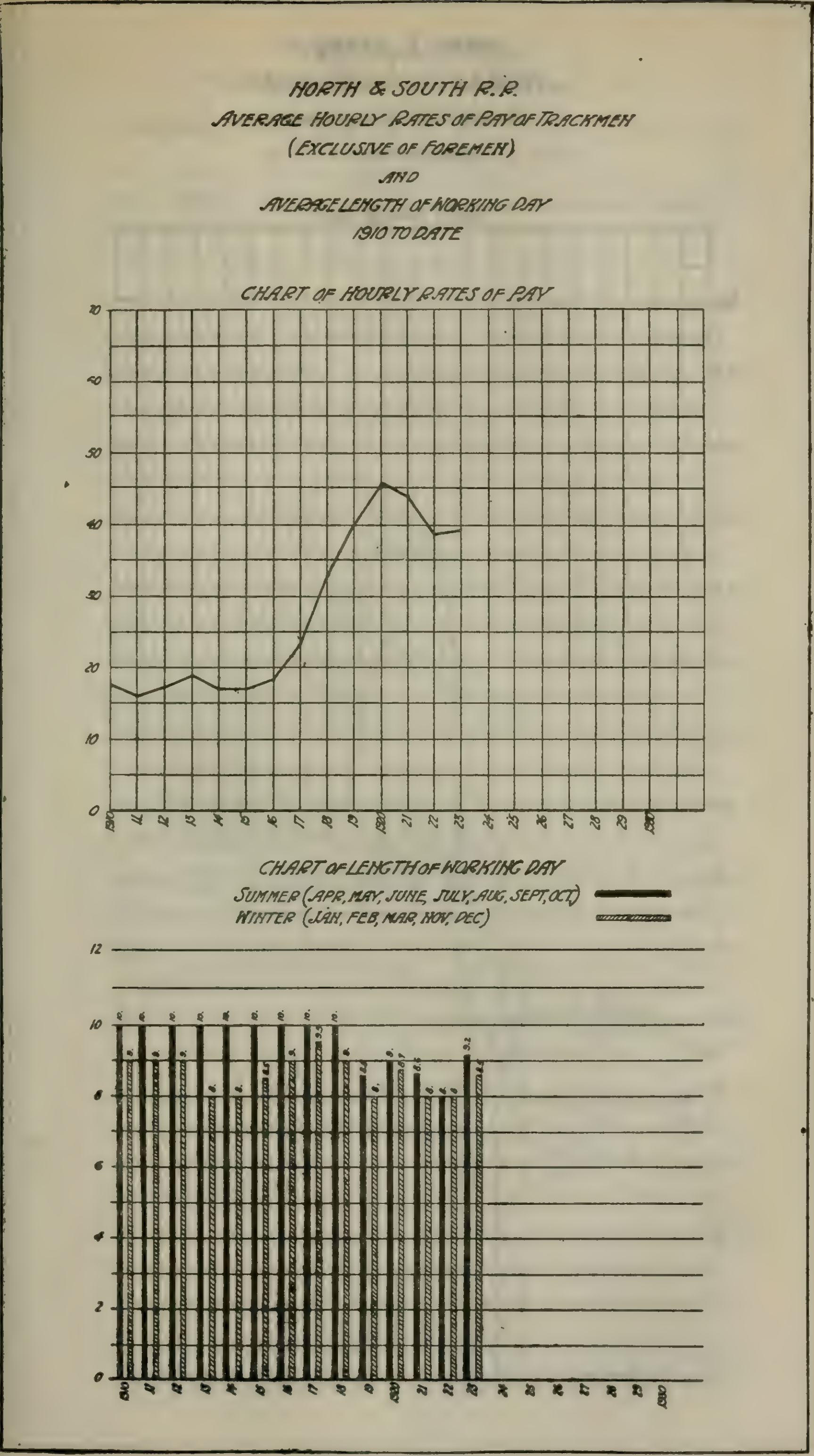
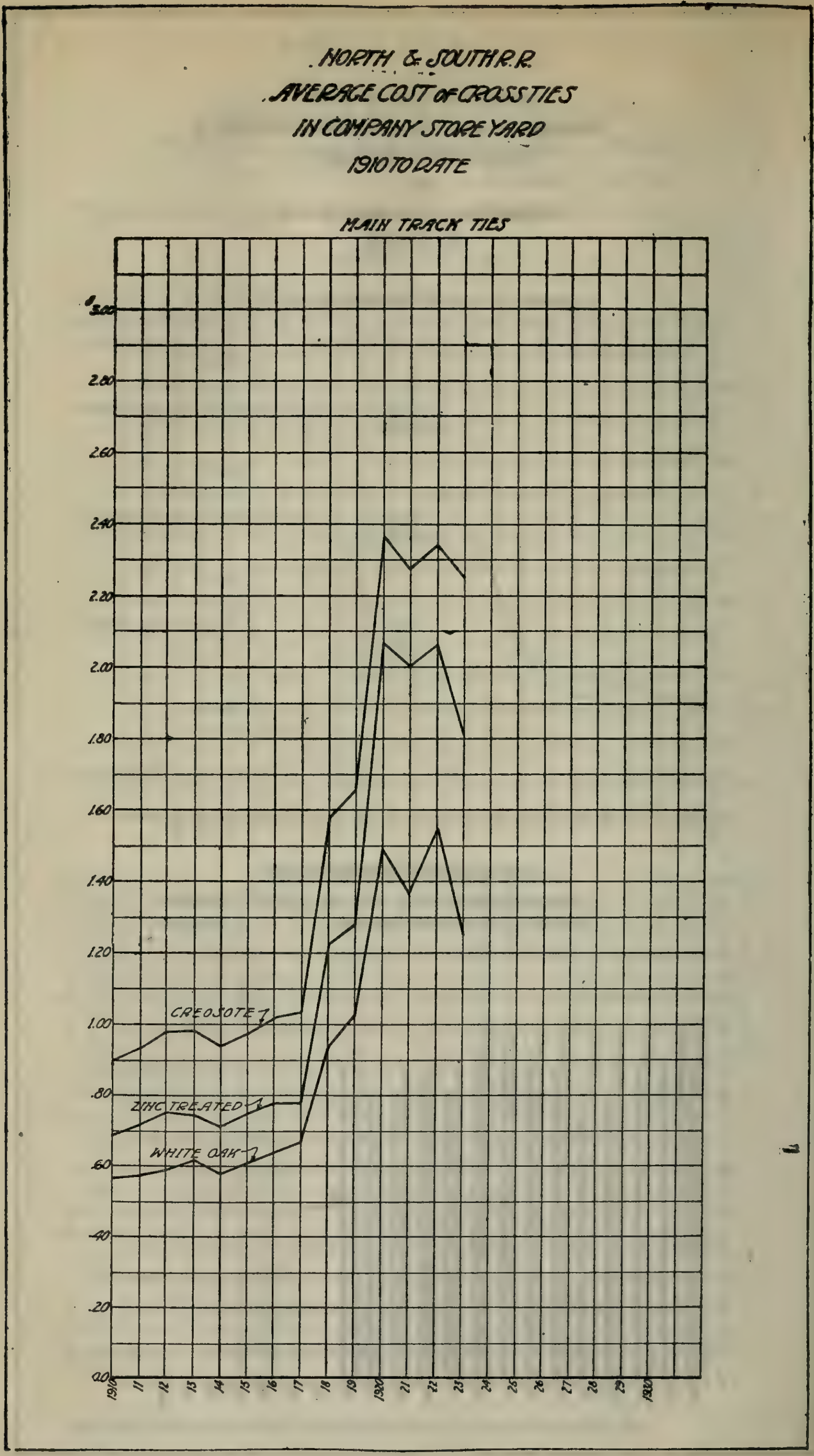

NORTH & SOUTH R.R.
AVERAGE HOURLY RATES OF PAY OF TRACKMEN
(EXCLUSIVE OF FOREMEN)
AND
AVERAGE LENGTH OF WORKING DAY
1910 TO DATE
CHART OF HOURLY RATES OF PAY
70
60
50
40
30
20
10
0
1910
11
12
13
14
15
16
17
18
19
1920
21
22
23
24
25
26
27
28
29
1930
CHART OF LENGTH OF WORKING DAY
SUMMER (APR, MAY, JUNE, JULY, AUG, SEPT, OCT)
WINTER (JAN, FEB, MAR, NOV, DEC)
12
10
8
6
4
2
0
10.
9.
10.
9.
10.
9.
10.
8.
10.
8.
10.
8.5
10.
9.
10.
9.5
10.
9.
8.6
8.
9.
8.7
8.6
8.
8.
8.
9.2
8.6
1910
11
12
13
14
15
16
17
18
19
1920
21
22
23
24
25
26
27
28
29
1930

Exhibit 6


NORTH & SOUTH R.R.
AVERAGE COST of CROSS TIES
IN COMPANY STORE YARD
1910 TO DATE
MAIN TRACK TIES
$3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
0.0
CREOSOTE
ZINC TREATED
WHITE OAK
1910
11
12
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1920
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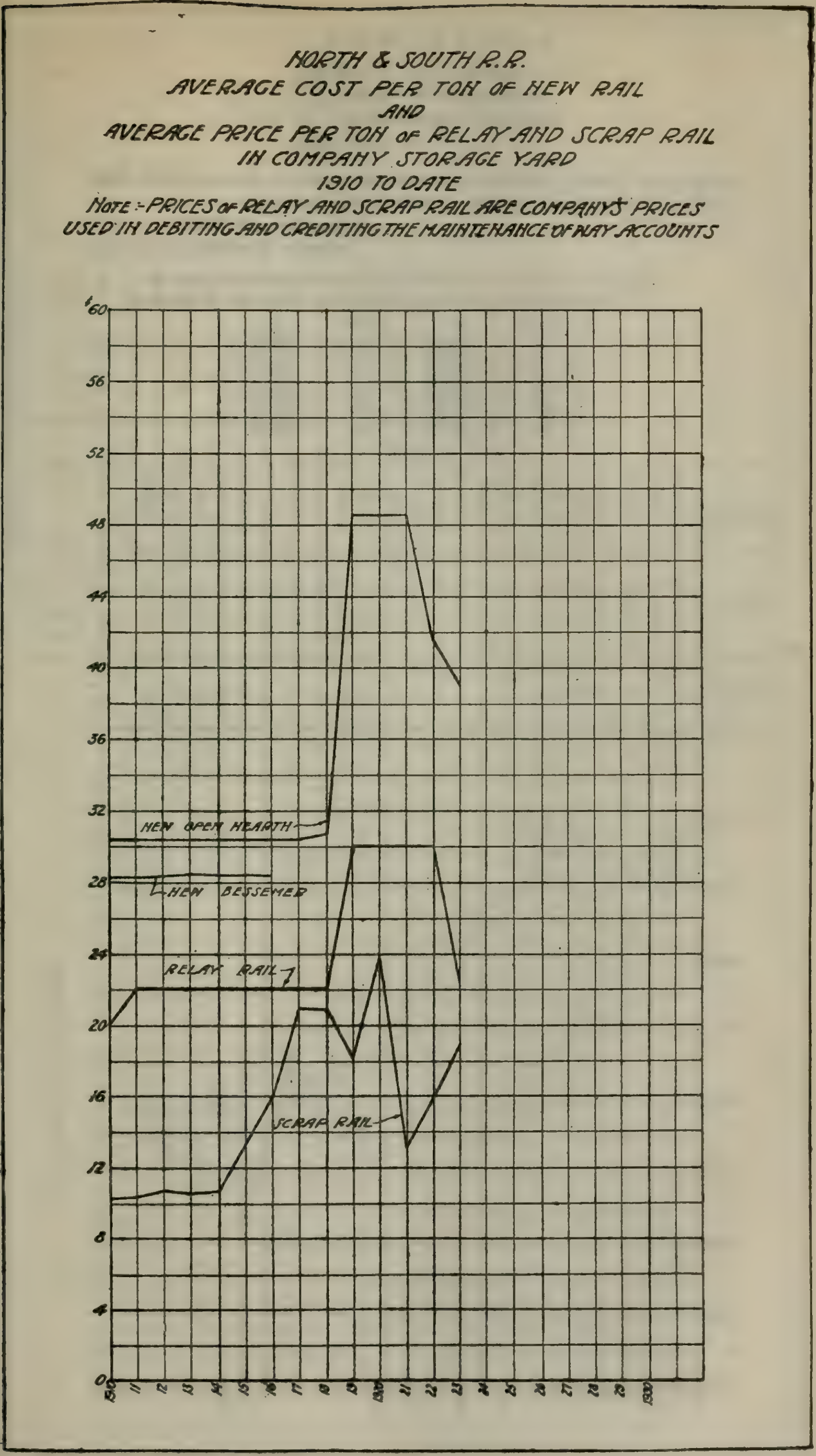
1930

Exhibit 7



NORTH & SOUTH R.R.
AVERAGE COST PER TON OF NEW RAIL
AND
AVERAGE PRICE PER TON OF RELAY AND SCRAP RAIL
IN COMPANY STORAGE YARD
1910 TO DATE
NOTE :- PRICES OF RELAY AND SCRAP RAIL ARE COMPANY'S PRICES
USED IN DEBITING AND CREDITING THE MAINTENANCE OF WAY ACCOUNTS

Exhibit 8

NORTH & SOUTH R.R.

COMPARISON OF TIE RENEWALS
ESTIMATED AND ACTUAL
FROM YEAR 1900 TO DATE

_ _ _ _ _ _ _ _ _ DIVISION

CHART ALSO SHOWS NUMBER OF TIES IN TRACK AND RENEWALS TO BE MADE EACH YEAR BASED ON VARYING LENGTHS OF LIFE OF TIES

ESTIMATED RENEWALS - - - - - - -
ACTUAL RENEWALS ————

STATEMENT OF ANNUAL RENEWALS TO BE MADE BASED ON 1,000,000 TIES IN TRACK AND VARYING LENGTHS OF LIFE OF TIES FROM 5 TO 20 YEARS

YEARS	TIES	YEARS	TIES
5	200,000	13	76,923
6	166,666	14	71,428
7	142,853	15	66,667
8	125,000	16	62,500
9	111,111	17	58,823
10	100,000	18	55,556
11	90,909	19	52,632
12	83,333	20	50,000

MAIN TRACKS

ANNUAL ESTIMATES	127,500	125,500	124,000	125,000	123,000	124,500	125,000	120,000	116,000	114,500	115,000	107,000	105,000	98,000	95,000	100,000	87,000	92,000	88,000	85,000	93,000	87,500	82,500	85,000	
ANNUAL RENEWALS	132,101	124,489	119,200	122,310	121,011	127,389	132,090	121,410	119,100	116,549	111,072	95,509	100,120	96,031	83,029	96,070	91,050	95,444	83,229	71,390	91,100	83,101	80,128	89,092	
AVERAGE LIFE TIES IN TRACK	7.0 YRS	7.3 "	7.5 "	7.7 "	7.8 "	8.0 "	8.0 "	8.0 "	8.1 "	8.2 "	8.2 "	8.5 "	8.7 "	9.0 "	9.2 "	9.6 "	9.8 "	10.0 "	10.5 "	10.8 "	10.9 "	11.1 "	11.3 "	11.5 "	

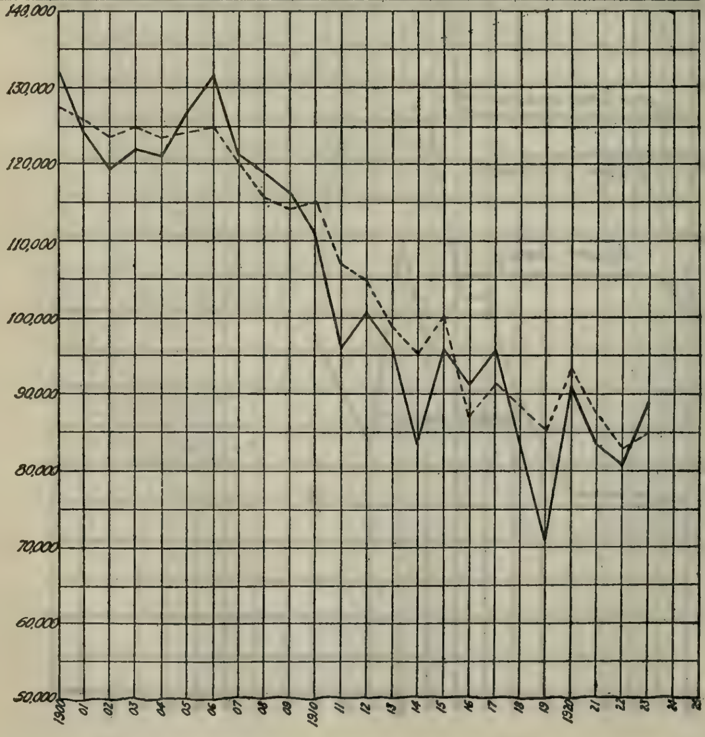


Exhibit 9

NORTH & SOUTH R.R.

RAIL IN TRACK AND RAIL RENEWALS

FROM YEAR 1910 TO DATE

---------- DIVISION

MAIN TRACKS

		1910	11	12	13	14	1915	16	17	18	19	1920	21	22	23
RAIL IN TRACK	GROSS TONS	37,884	38,532	38,844	39,232	39,612	40,060	42,270	44,416	44,864	45,440	46,400	47,040	48,000	49,937
	TRACK MILES	300	300	300	300	300	300	310	320	320	320	320	320	320	325
RAIL RENEWALS	GROSS TONS	1,884	2,198	2,512	2,198	1,570	2,198	3,140	2,826	2,198	2,826	4,710	3,140	4,710	5,652
	TRACK MILES PERCENT	4.0	4.67	5.33	4.67	3.33	4.67	6.45	5.63	4.38	5.63	9.38	6.45	9.38	11.25
	TRACK MILES	12.0	14.0	16.0	14.0	10.0	14.0	20.0	18.0	14.0	18.0	30.0	20.0	30.0	36.0

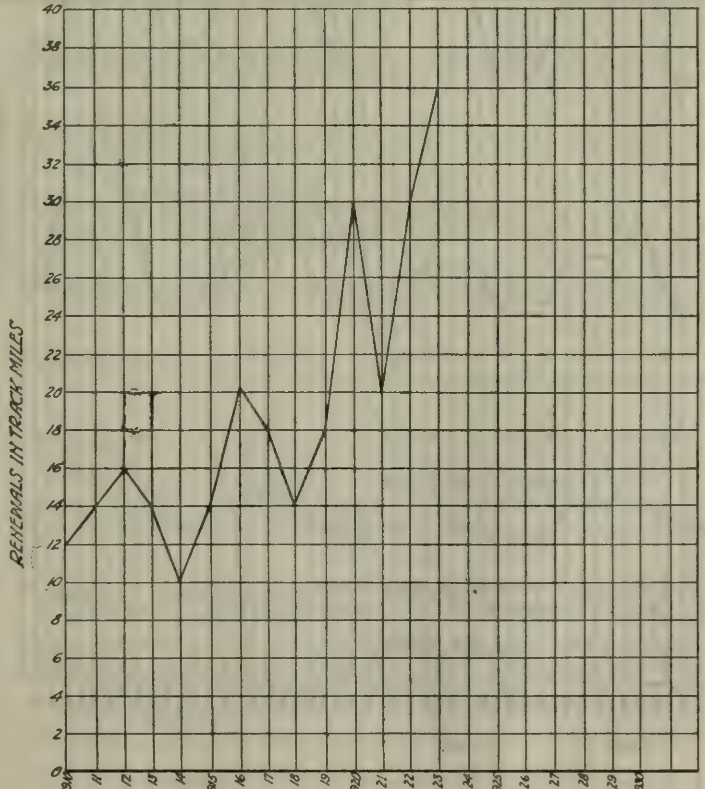


Exhibit 10

NORTH & SOUTH R. R.

MAINTENANCE OF WAY AND STRUCTURES

TOTAL HOURS WORKED FOR CURRENT MONTH

AND

BY MONTHS FOR THREE PREVIOUS YEARS

PERIOD............... DIVISION..........

NOTE:-FOREMEN HOURS ARE INCLUDED

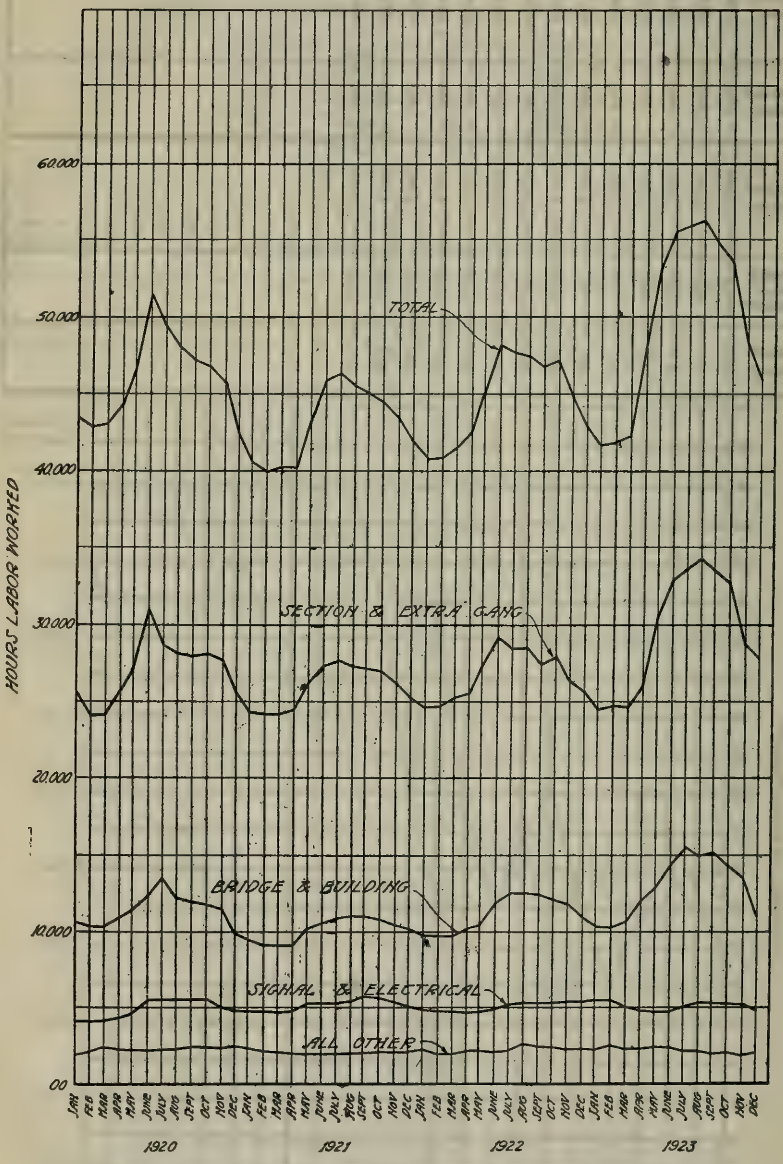
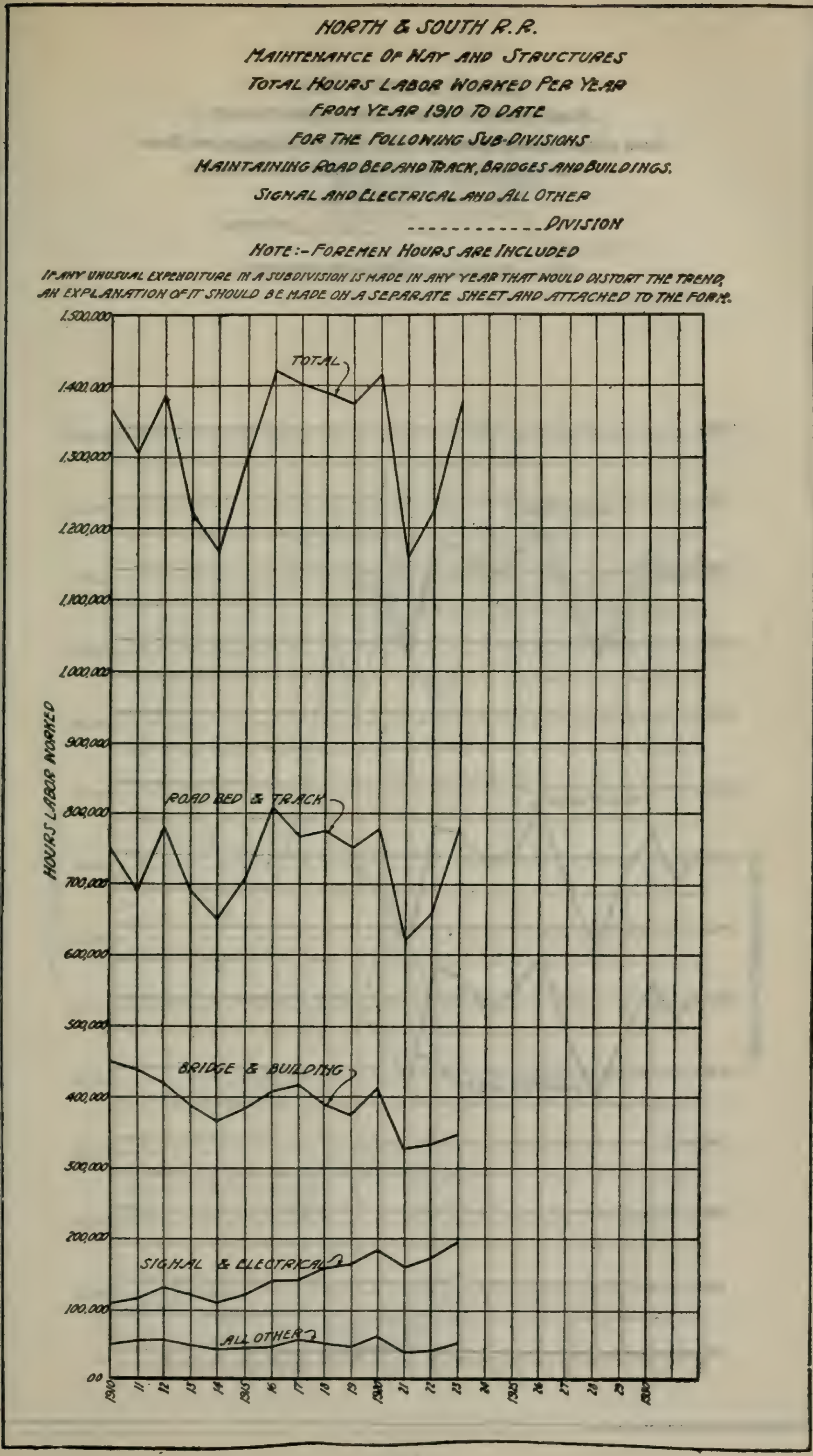
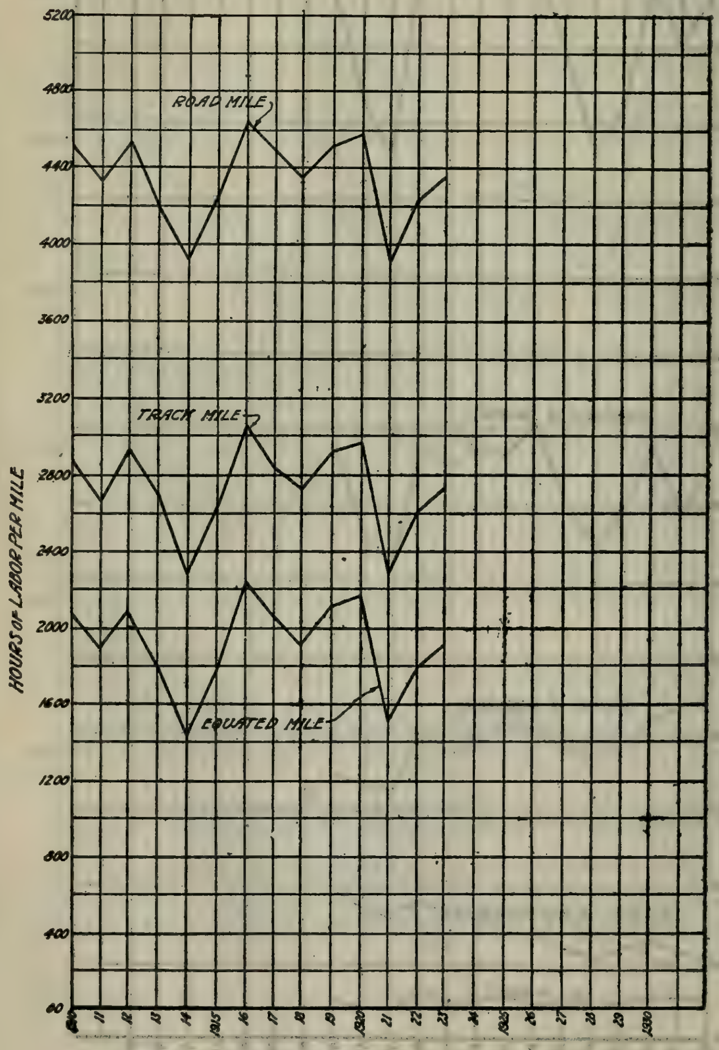


Exhibit 11



NORTH & SOUTH R.R.
MAINTENANCE OF WAY AND STRUCTURES
TOTAL HOURS LABOR WORKED PER YEAR
FROM YEAR 1910 TO DATE
FOR THE FOLLOWING SUB-DIVISIONS
MAINTAINING ROAD BED AND TRACK, BRIDGES AND BUILDINGS.
SIGNAL AND ELECTRICAL AND ALL OTHER
------------DIVISION
NOTE:-FOREMEN HOURS ARE INCLUDED
IF ANY UNUSUAL EXPENDITURE IN A SUBDIVISION IS MADE IN ANY YEAR THAT WOULD DISTORT THE TREND, AN EXPLANATION OF IT SHOULD BE MADE ON A SEPARATE SHEET AND ATTACHED TO THE FORM.

Exhibit 12



NORTH & SOUTH R.R.
MAINTENANCE OF WAY AND STRUCTURES
TOTAL HOURS LABOR WORKED MAINTAINING ROADBED AND TRACK
PER ROAD MILE, EQUATED MILE AND TRACK MILE
FROM YEAR 1910 TO DATE
-------------- DIVISION

NOTE:-FOREMEN HOURS ARE INCLUDED

Exhibit 13

NORTH & SOUTH R. R.

MAINTENANCE OF WAY AND STRUCTURES

TOTAL EXPENDITURES

FROM YEAR 1910 TO DATE

............DIVISION

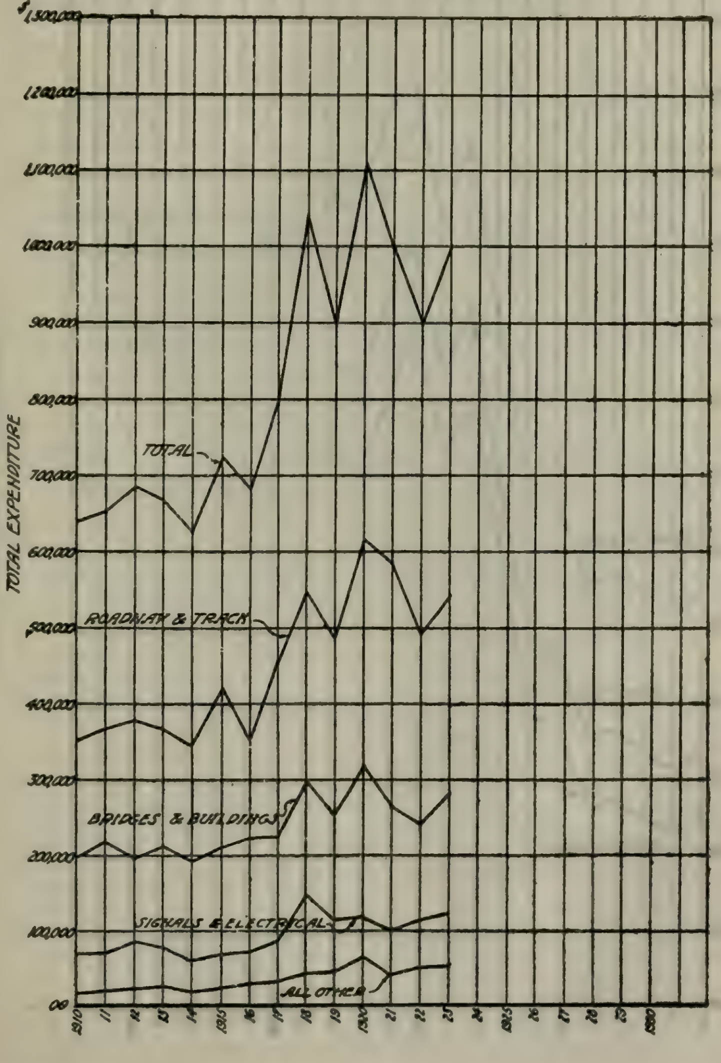
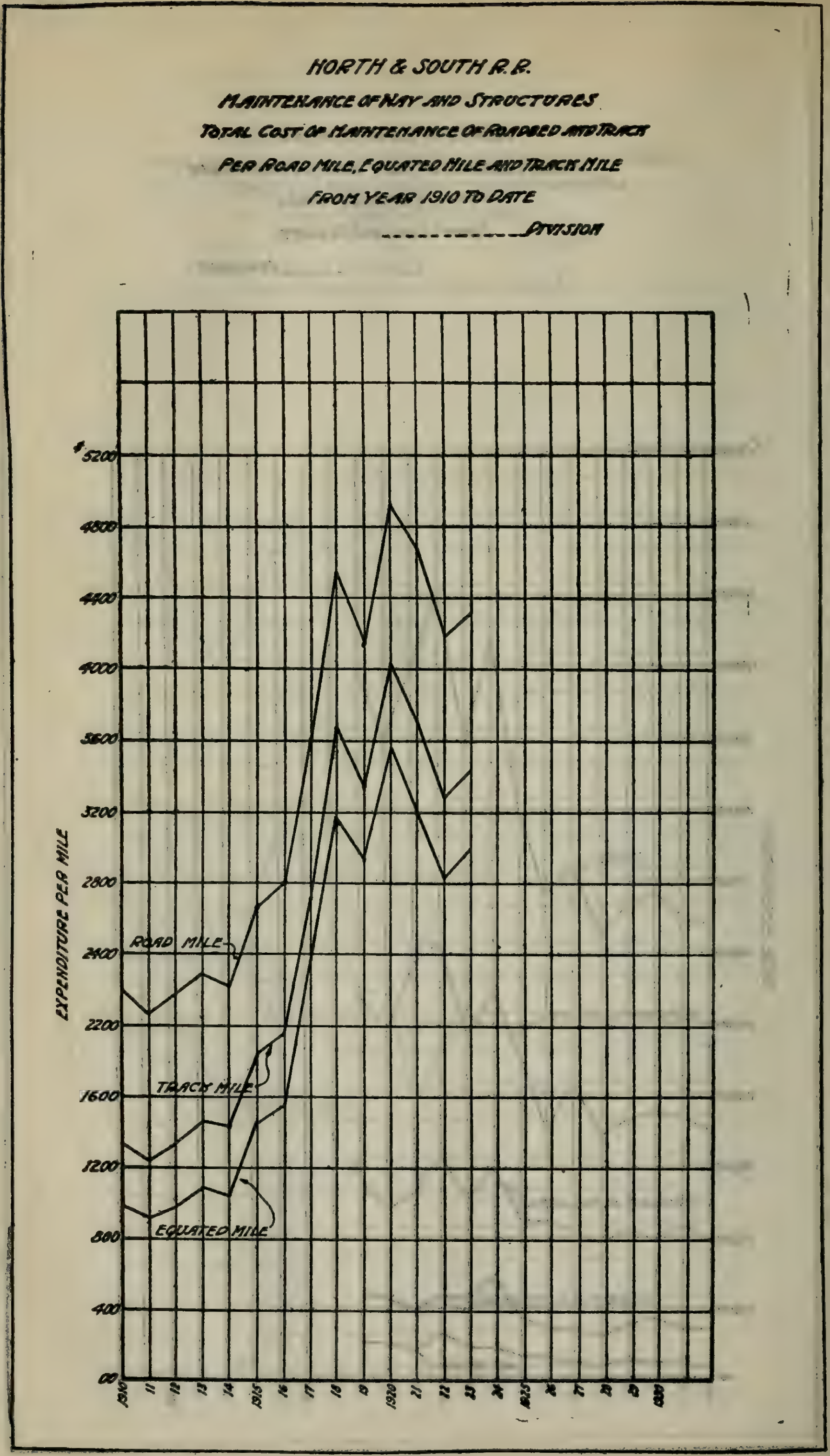
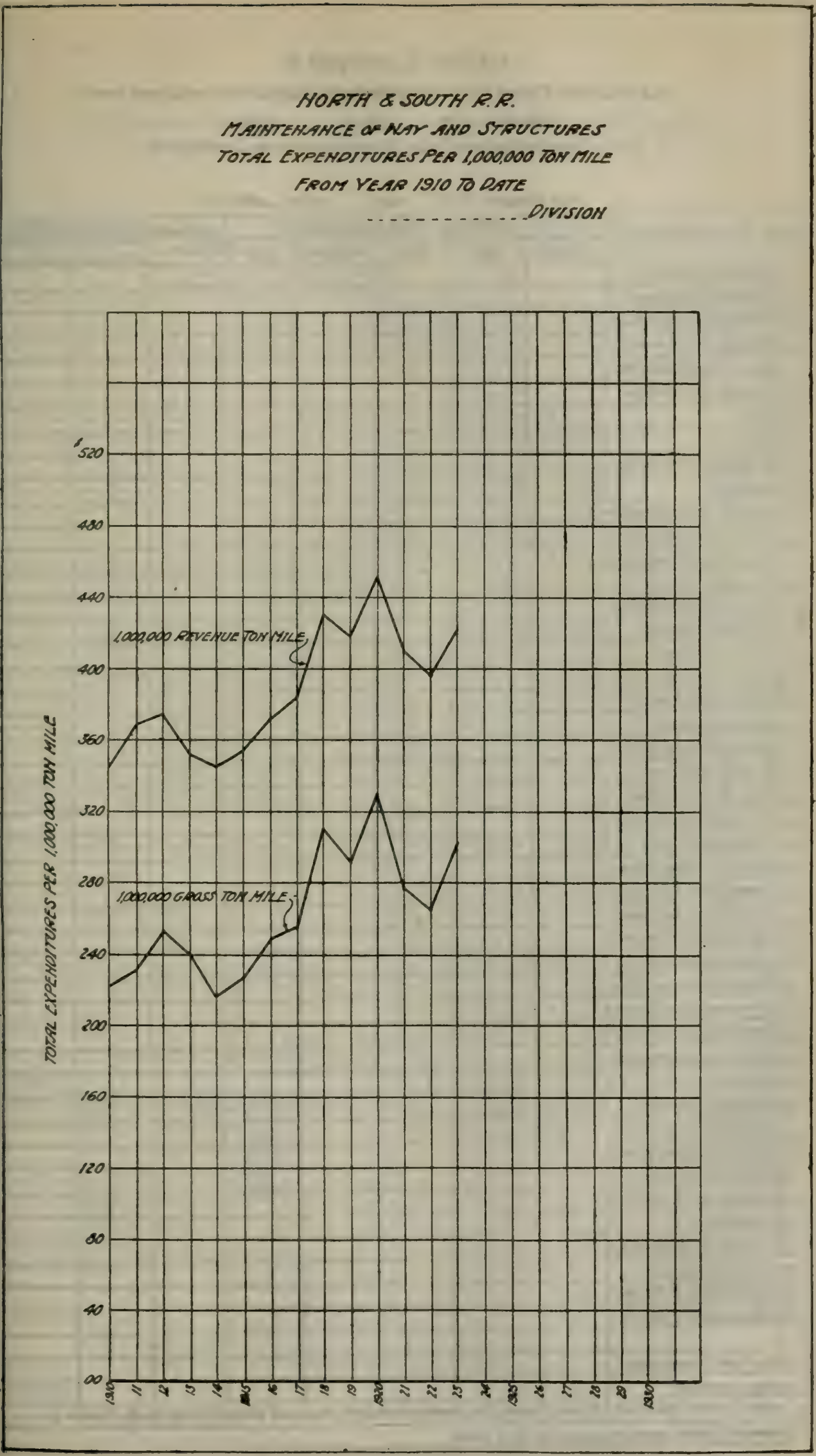


Exhibit 14



NORTH & SOUTH R.R.
MAINTENANCE OF WAY AND STRUCTURES
TOTAL COST OF MAINTENANCE OF ROADBED AND TRACK
PER ROAD MILE, EQUATED MILE AND TRACK MILE
FROM YEAR 1910 TO DATE
____________ DIVISION

Exhibit 15



NORTH & SOUTH R.R.
MAINTENANCE OF WAY AND STRUCTURES
TOTAL EXPENDITURES PER 1,000,000 TON MILE
FROM YEAR 1910 TO DATE
.............DIVISION

Exhibit 16

NORTH & SOUTH R.R

ESTIMATED EXPENDITURES OF MAINTENANCE OF WAY AND STRUCTURES

FOR MONTH OF ....JULY..... 1923

WITH COMPARISON OF ACTUAL EXPENDITURES OF SAME MONTH

FOR YEARS 1920.....1921.....1922.. AND 1923..

NO	ACCOUNT	ACTUAL EXPENDITURES					ESTIMATED 1923	INCREASE - DECREASE -	
		1920	1921	1922	AVERAGE	1923		ESTIMATED TO AVERAGE	ESTIMATED TO LAST YEAR
201	SUPERINTENDENCE								
202	ROADWAY MAINTENANCE								
204	UNDERGROUND POWER TUBES								
206	TUNNELS AND SUBWAYS								
208	BRIDGES TRESTLES & CULVERTS								
210	ELEVATED STRUCTURES								
212	TIES								
214	RAIL								
216	OTHER TRACK MATERIAL								
218	BALLAST								
220	TRACK LAYING & SURFACING								
221	RIGHT OF WAY FENCES								
223	SNOW AND SAND FENCES, ETC								
225	CROSSINGS & SIGNS								
227	STATION & OFFICE BUILDINGS								
229	ROADWAY BUILDINGS								
231	WATER STATIONS								
233	FUEL STATIONS								
235	SHOPS & ENGINE HOUSES								
237	GRAIN ELEVATORS								
239	STORAGE WAREHOUSES								
241	WARVES & DOCKS								
243	COAL & ORE WHARVES								
245	GAS PRODUCING PLANTS								
247	TELEG & TELEP LINES								
249	SIGNALS & INTERLOCKERS								
251	POWER PLANT PIPE LINES								
253	POWER PLANT BUILDINGS								
255	POWER SUBSTATION BUILDINGS								
257	POWER TRANSMISSION SYS								
259	POWER DISTRIBUTION SYSTEMS								
261	POWERLINE POLES & FIXTURES								
263	UNDERGROUND CONDUITS								
265	MISCELLANEOUS STRUCTURES								
267	PAVING								
269	ROADWAY MACHINES								
271	SMALL TOOLS & SUPPLIES								
272	REMOVING SNOW ICE & SAND								
273	ASSTS PUBLIC IMPS								
274	INJURIES TO PERSONS								
275	INSURANCE								
276	STATIONERY & PRINTING								
277	OTHER EXPENSES								
278	MAINTAINING JT. TKS. DR.								
279	MAINTAINING JT. TKS. CR.								
TOTALS FOR COMPARISON									
TOTALS—PERIOD									

NOTE:— WORK SHEET OF ESTIMATE AND EXPLANATION OF ANY UNUSUAL EXPENDITURE TO BE SHOWN ON SEPARATE SHEET AND ATTACHED TO THIS FORM.

Exhibit 17

NORTH & SOUTH R.R.

ESTIMATED EXPENDITURES FOR MAINTENANCE OF WAY AND STRUCTURES

________________ DIVISION, FOR MONTH OF ______________ 192__

FORCE					EXPENSES			
CLASSIFICATION OF EMPLOYES	No OF EMPLOYES	MAN HOURS	RATE OF PAY	TOTAL AMOUNT OF WAGES	ACCOUNT	LABOR	MATERIAL	TOTAL
					202A DITCHING & EMBANKING			
					218-220 A BALLAST & APPLYING BALLAST			
					212-220 B TIES & APPLYING TIES			
					214-220 C RAILS & APPLYING RAILS			
					216 A FROGS & SWITCHES			
					216 B OTHER TRACK MATERIAL			
					272 REMOVAL OF SNOW SAND & ICE			
					202 C REMOVAL OF GRASS & WEEDS			
					269-271 TOOLS & ROADWAY MACHINES			
					202 B-220 D REPAIRS OF ROADWAY & TRACK			
					202 E-220 E EXTRAORDINARY REPAIRS			
					225 A CROSSINGS & SIGNS			
					221 RIGHT OF WAY FENCES			
					223 SNOW & SAND FENCES, ETC.			
					235 B SHOP GROUNDS			
					TOTAL			
					201 A ADMINISTRATION			
					202 B & C SUPERINTENDENCE			
					202 D WATER FRONT PROTECTION			
					208 A BRIDGES – TIMBER			
					208 B BRIDGES – PERMANENT			
					206 TUNNELS & SUBWAYS			
					235 A SHOPS & ENGINEHOUSES			
					227 STATION & OFFICE BUILDINGS			
					229-253-265 MISCELLANEOUS STRUCTURES			
					231 WATER STATIONS			
					233 FUEL STATIONS			
					241 DOCKS & WHARVES			
					267-273 PAVING & SPECIAL ASSESSMENTS			
					278 MAINT. JOINT FACILITIES – DR.			
					279 MAINT. JOINT FACILITIES – CR.			
					225 B HIGHWAY & ST CROSSING BELLS			
					249 A INTERLOCKING PLANTS			
					249 B BLOCK SIGNALS			
					249 C OTHER SIGNALS			
					247 TELEGRAPH & TELEPHONE LINE			
					274 INJURIES TO PERSONS			
					275 INSURANCE			
					276 STATIONERY & PRINTING			
					277 OTHER EXPENSES			
					TOTAL			
TOTAL					GRAND TOTAL			

QUANTITIES OF MAJOR MATERIALS			
CU YARDS		ROCK BALLAST	
" "		GRAVEL	
" "		CHATTS	
" "		SLAG	
" "		CINDERS	
CROSS TIES			
SETS SWITCH TIES			
BRIDGE TIES			
MILES NEW	LB RAIL		DIST
" "	" "		"
" S.H.	" "		"
" "	" "		"

SPECIAL WORK	EXPENSE
TOTAL	

NOTE:- WORK SHEET OF ESTIMATE AND EXPLANATION OF ANY UNUSUAL EXPENDITURE TO BE SHOWN ON SEPARATE SHEET AND ATTACHED TO THIS FORM.

APPROVED

____
SUPERINTENDENT

____
ENGINEER.

COMMITTEE XII

RULES AND ORGANIZATION

[1]MANUAL OF INSTRUCTIONS FOR THE GUIDANCE OF ENGINEERING FIELD PARTIES

(I) GENERAL

Purpose and Scope

The amount and kind of information to be obtained and the degree of precision required depend upon the purpose and scope of the survey; hence careful and constant consideration of these features is essential to the proper planning and execution of field work.

The error, if any, should be in the direction of too much information or excess precision; but large errors in either direction are inexcusable as they constitute an economic waste.

(II) BEFORE GOING INTO THE FIELD

The "Chief of Party," being responsible to his superiors for results and to his men for their welfare, should familiarize himself as thoroughly as possible with the conditions to be encountered before starting field work.

With the advice and under the instructions of his superiors the Chief of Party should consider the following items and make his preparations accordingly:

Size of Party

The size of the party should be adapted to the work to be done, i. e., a sufficient number of engineering assistants with ample training for their respective positions, and of intelligent helpers should be provided to handle the work expeditiously and economically.

Personnel of Party

The Chief of Party should have the right to select the members of the party whenever feasible; especially on extensive surveys, when he should satisfy himself that the men will be able to stand the work under the climatic and other conditions encountered.

Local people should be employed as helpers whenever possible so that advantage may be taken of their knowledge of local conditions, and sometimes the sympathetic interest of the community may be enlisted by this practice.

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[1] Adopted, Vol. 22, 1921, pp. 297, 1078.

Organization

The relative rank of the various members of the party or sub-parties under any and all circumstances should be specified clearly, but with the understanding that changes may be made by the Chief of Party as the exigencies of the work require.

Personal Supplies

The Chief of Party should instruct the men as to the amount and kind of clothing and personal supplies with which to provide themselves, setting limits of weight or bulk whenever necessary; with due consideration to the following:

Transportation facilities,
Climate, including extremes of temperature, rainfall, etc.,
Country to be traversed,
Duration of trip or expedition, and
Possibility of securing clothes and supplies on the work.

Transportation

Mode or modes of travel:

Steam railway,
Electric railway,
Automobile,
Motor car,
Horse and wagon,
Pack train,
Boats or canoes, and
Dog sleds, etc.

Availability of forage for animals and gasoline, oils, and repair parts for motor vehicles.

Provision for overcoming difficulties with the mode or modes of travel selected.

Housing and Boarding Men

If in hotels, the spacing and capacity,
If in farm houses, the spacing and capacity,
If in camp cars, the number and kind required, and
If in tents, the number necessary and the proper design to withstand storms, animals and insects. Also whether stoves, wooden floors, flies, etc., are needed.

Supplies

Food supplies—articles and amount of each required to take care of party until it can be replenished. Use of local foods should be encouraged.

First aid outfits and instructions for their use.

Additional medical supplies and instructions for their use, the quantity and assortment to depend upon possibility of securing such supplies in the country to be traversed.

Methods of preserving foods and substitutes for those that can not be preserved.

Equipment

Instrumental equipment, including drafting, should be ample; with duplicates of those articles difficult or impossible to secure in the country traversed or within a reasonable time.

Cooking outfit should be reasonably complete, considering the difficulties of transportation.

In addition to tents, mosquito head nets, mosquito proof tents, snow shoes, snow glasses, portable boats, ropes, hammocks, cots, blankets, etc., may be necessary in some localities.

Camp Locations

Camp sites should be carefully selected with due regard to:

Supply of potable water,
Sanitary facilities required and method of providing them,
Protection from storms, and
Healthfulness.

Communication

Facilities and methods of securing mail, and
Other sources of communication that may be arranged.

(III) AFTER ARRIVING IN THE FIELD

After the party arrives in the field, the Chief of Party should not be overburdened with details, but should have ample time to plan the work and anticipate requirements. He should first, therefore, give instructions covering the following items:

Duties

The duties of the various members of the party under differing circumstances and for different periods of the day should be outlined, in so far as is practicable, such as:

When starting the day,
When completing the day,
When setting up camp,
When breaking camp, and
When in camp.

The assembling of each party, or sub-party, at the close of the day's work should be insisted upon, so that no one may be lost or left alone in case of accident.

Supplies and Equipment

Care should be used in the handling and use of all supplies and equipment so that injuries and waste may be avoided.

Special instructions should be given in regard to leaving instruments and other equipment in the field overnight.

Personal property of each man should bear individual marks or be of distinctive color sufficient to keep it from being mixed with the property of others.

Treatment of Property of Others

Amount of care to be exercised when passing through cultivated fields.

General rules as to when timber should be cut and when to triangulate or offset around it.

Cutting of stakes from timber, or material at hand, to avoid using property upon which others may set a value.

Kind of stakes to be used through fields to avoid injuries to farm machinery, or the removal of stakes after the party has passed.

Conduct of Party

Conduct of party should be such as to create and maintain a good feeling among the residents; local customs should be observed and care taken not to stir up local prejudices.

Conduct at farm houses should indicate an appreciation of the fact that the people have inconvenienced themselves in order to accommodate the party. Meddling with their belongings should be prohibited.

Field Notes

The forms for field notes should be specified and kept uniform throughout the survey, with due regard to ease of plotting and their use by others not connected with the survey.

All notes should be titled, dated and indexed, and should show the name of the engineer in charge and of the person making the notes.

The title should indicate the name, letter or number of the line, and notes for all abandoned lines should be crossed out and marked "Abandoned."

Transit and topography notes should run up the page and the latter should give the scale at the beginning and end of each line.

An index of all field books and their contents should also be kept.

Maps

Maps should be kept up to date and should conform in all respects to the recommendations of the Manual of the A.R.E.A.

Reference Points and Bench Marks

When a line is finally established, bench marks should be placed at permanent locations and a large number of alinement points should be referenced in a permanent manner. Reference points should be so placed as to make the recovery of the alinement point as convenient as possible and in such positions that they will not be disturbed by the process of construction.

[2]MANUAL OF RULES FOR THE GUIDANCE OF EMPLOYEES OF THE MAINTENANCE OF WAY AND STRUCTURES DEPARTMENT

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[2] Adopted, Vol. 22, 1921, pp. 802, 1082; Vol. 23, 1922, pp. 985, 1161; Vol. 25, 1924, pp. 550, 1318; Vol. 26, 1925, pp. 160, 1271; Vol. 27, 1926, pp. 66, 1269; Vol. 28, 1927, pp. 415, 1400; Vol. 29, 1928, pp. 515, 1310; Vol. 30, 1929, pp. 383, 1390.

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- STRETCHERS 2245-2248

NOTE:—Items marked * not yet submitted.

MANUAL OF RULES FOR THE GUIDANCE OF EMPLOYEES OF THE MAINTENANCE OF WAY AND STRUCTURES DEPARTMENT

GENERAL NOTICE

Safety is of the first importance in the discharge of duty.

Obedience to the rules is essential to safety.

To enter or remain in the service is an assurance of willingness to obey the rules.

The service demands the faithful, intelligent and courteous discharge of duty.

To obtain promotion capacity must be shown for greater responsibility.

GENERAL RULES

1. Employees whose duties are prescribed by these rules must provide themselves with a copy.

2. Employees must be conversant with and obey the rules and special instructions. If in doubt as to their meaning they must apply to proper authority for an explanation. Supervisory employees must know that the rules and instructions are understood and complied with by those under them.

3. Employees must pass the required examinations.

4. Any violation of the rules or special instructions must be reported.

5. The use of intoxicants by employees while on duty is prohibited. Their use, or the frequenting of places where they are sold, is sufficient cause for dismissal.

6. In case of danger to the Company's property, employees must unite to protect it.

7. Employees must do all in their power to prevent accidents, even though in so doing they may necessarily perform the duties of others.

8. Employees are prohibited from incurring any obligation on account of the Company or from using the Company's credit, unless authorized by the proper officer.

9. Unauthorized assignment of wages by employees is prohibited and will be sufficient cause for dismissal. Employees failing or refusing to pay their just debts, or against whom bills are frequently presented to the Company for payment, or whose wages have been garnisheed, will, unless satisfactory reason is given, be dismissed from the service.

10. Employees must devote themselves exclusively to the service of the Company, and must not connect themselves with any other trade or business without permission from the proper officer.

11. Employees must not absent themselves from duty without permission. They must not exchange duties with others, or engage substitutes without proper authority.

12. The articles furnished by the Company for the use of employees must, on their leaving the service, be returned to the proper officer.

13. Employees subject to emergency call must keep their immediate superior and the train dispatcher informed as to their whereabouts at all times.

14. Employees whose duties are in any way affected by the time table, must have a copy of the current time table with them while on duty and must be familiar with the rules and regulations therein.

Employees must carefully observe signals displayed by all trains, and assure themselves before obstructing the track that all trains and sections due have passed.

Employees are especially cautioned that extra and special trains may be run at any time, and that trains may run at any time upon any track in either direction, without notice to them. They must be governed accordingly and exercise proper care to avoid accident.

15. Employees are prohibited from asking or receiving fees or contributions from subordinates, fellow-employees or the public.

16. Employees are subject to record discipline, suspension, or dismissal for cause.

17. Employees must know that the machinery, tools and appliances which they are to use are in suitable and proper condition.

18. Employees will be regarded as in line of promotion; advancement depending upon the faithful discharge of duty and capacity for increased responsibility.

19. Complete service and discipline records of all supervising employees must be kept in the office of the ....

20. Employees must observe trains closely, and if anything dangerous is noted, must call attention of the trainmen to the fact by signal or wire.

21. When work or other cause renders the track or bridges unsafe for passage of trains, protection to trains must be provided in accordance with instructions.

When the track is safe for trains to pass, but at reduced speed, protection must be provided by displaying the proper signals from each end of the section of track on which the speed is restricted. Resume signals must be displayed to indicate where the normal speed may be resumed. On multiple tracks each track involved must be protected in the same manner as if it were single track.

The Superintendent must be notified at once by wire of the speed to be observed over the track protected by "Slow" signals. Where the obstruction of a track is continued during the night, proper night signals must be displayed.

22. In case of impassable or obstructed track, flagging is the first duty and repairs must wait, if necessary, until signals have been displayed.

23. No work that will interfere with the safe passage of trains at full speed must be undertaken during fogs or blinding storms, except in emergency.

24. Disregard of stop or caution signals, excessive speed of trains, or failure to answer signals properly must be reported, with a full statement of facts.

25. Employment of minors will not be permitted, except as allowed by law, and then only after written consent and release on the proper form has been obtained from parents or guardians.

26. When a train is approaching or passing, employees must not unlock a main track switch nor stand within .... feet of such a switch.

Immediately upon closing and locking a main track switch, the employee doing so must observe if the points fit properly, and must call the attention of those with him in words equivalent to the statement: "I have closed and locked the switch." This statement must be acknowledged in words by one of the employees to whom it is addressed.

27. Motor, hand, velocipede and push cars must be used for Company business only, and must be operated in accordance with the special rules governing their use.

28. In case of injury, however slight, to himself or to any one under his supervision, or in case of injury to others which has not been reported by other employees, the Foreman must immediately make a report by wire to his Supervisor, followed by a written report on the prescribed form.

29. The proper officer of the Company must be informed promptly regarding contemplated public improvements or enacted ordinances which would in any way affect its interests. Supervisors, Foremen and other employees must make prompt report and forward at once to their immediate superiors any printed public notices or other matter, with all the information available.

30. Employees must not use the telegraph unnecessarily. All messages must be as brief as is consistent with a clear understanding of their meaning.

31. Employees must not permit, except by proper authority, experimental trials of appliances or devices, nor give out information of the results of any such trial.

32. Employees must conform to the prescribed standards, plans and specifications in the execution of work under their supervision.

OPERATING RULES

(A Rule preceded by an asterisk is a Standard Code rule of the American Railway Association.)

Standard Time

*100. Standard time obtained from .... observatory, will be transmitted to all points from designated offices at .... M. daily.

*101. Watches that have been examined and certified to by a designated inspector must be used by conductors, enginemen and .... The certificate in prescribed form must be renewed and filed with .... every ....

(Form of Certificate)

CERTIFICATE OF WATCH INSPECTOR

This is to certify that on.., 19....
the watch of...
employed as ....
on the .... R.................
was examined by me. It is correct and reliable, and, with proper care should run within a variation of thirty seconds per week.
Name of Maker..
Grade ....
Number of Movement..
Open or Hunting Case...
Metal of Case..
Signed...
Inspector.
Address...

*102. Watches of conductors, enginemen and .... must be compared before commencing each day's work, with a clock designated by timetable as a standard clock. The time when watches are compared must be registered on a prescribed form.

103. If access to a standard clock is not possible comparison must be made with a responsible employee who has compared with a standard clock.

*104. Employees whose duties may require them to give signals, must provide themselves with the proper appliances, keep them in good order, and ready for immediate use.

*105. Flags of the prescribed color must be used by day, and lights of the prescribed color by night.

*106. Day signals must be displayed from sunrise to sunset, but when day signals cannot be plainly seen, night signals must be used in addition. Night signals must be displayed from sunset to sunrise.

*107. *Color-Signals.*

Color	*Indication*
(a) Red.	Stop.
(b) ———	Proceed at restricted speed and for other uses prescribed by the rules.
(c) ———	Proceed, and for other uses prescribed by the rules.
(d) Green and White.	Flag Stop. See Rule 151.
(e) Blue.	See Rule 122.
(f) Purple.	Stop (indication for dwarf signals).

*108. A train finding a fusee burning on or near its track must stop and extinguish the fusee, and then proceed at restricted speed.

109. Maintenance of Way employees must not disturb burning fusees on or near the track placed there by trainmen.

*110. *Hand, Flag and Lamp Signals.*

Manner of Using	*Indication*
(a) Swung across the track.	Stop.
(b) Held horizontally at arm's length.	Reduce speed.
(c) Raised and lowered vertically.	Proceed.
(d) Swung vertically in a circle at half-arm's length across the track.	Back.
(e) Swung vertically in a circle at arm's length across the track, when running.	Train has parted.
(f) Swung horizontally above the head when standing.	Apply air brakes.
(g) Held at arm's length above the head when standing.	Release air brakes.

*111. Any object waved violently by anyone on or near the track is a signal to stop.

**Emergency Signals at Interlocking Stations and Other Designated Points. (Whistle or Horn.)*

NOTE.—The signals prescribed are illustrated by "o" for short sounds; "—" for longer sounds. Railroads may add to these signals to meet their requirements.

Sound	*Indication*
(a) ———	All trains within interlocking and .... limits stop immediately.
(b) o o	Resume normal movement after receiving the proper signal or permission from the signalman.
(c) o o o	Whistle or horn test.
(d) o o o o	Call signal maintainer or repairman.

*112. *Engine Whistle Signals.*

NOTE.—The signals prescribed are illustrated by "o" for short sounds; "—" for longer sounds. The sound of the whistle should be distinct, with intensity and duration proportionate to the distance signal is to be conveyed.

Sound	*Indication*
(a) o	Apply brakes. Stop.
(b) — —	Release brakes. Proceed.
(c) — o o o	Flagman protect rear of train.
(d) — — — —	Flagman may return from west or south, as prescribed by Rule 157.
(e) — — — — —	Flagman may return from east or north, as prescribed by Rule 157.
(f) — — —	Train parted, to be repeated until answered by the signal prescribed by Rule 110 (e). Answer to Rule 110 (e).
(g) o o	Answer to Rule 112 (k) or any signal not otherwise provided for.
(h) o o o	When standing, back. Answer to Rule 110 (d).
(j) o o o o	Call for signals.
(k) — o o	To call the attention of yard engines, extra trains or trains of the same or inferior class or inferior right to signals displayed for a following section. If not answered by a train, the train displaying signals must stop and ascertain the cause.
(l) — — o o	Approaching public crossings at grade. To be prolonged or repeated until crossing is reached.
(m) ————————	Approaching stations, junctions, railroad crossings at grade and .... as may be required.
(n) — — o	Approaching meeting or waiting points.
(o) o —	Inspect train line for leak or for brakes sticking.
(p) Succession of short sounds.	Alarm for persons or live stock on the track.
(q) — o	When running against the current of traffic: (1) Approaching stations, curves, or other points where view may be obscured. (2) Approaching passenger or freight trains and when passing freight trains. (3) Preceding the signals prescribed by Rules (d), (e), (r), (s), (t), (u), (v) and (w).
	For additional tracks the following signals may be used)
(r) — — — — — o	Flagman may return from east or north on .... track.
(s) — — — — o	Flagman may return from west or south on .... track.
(t) — — — — — o o	Flagman may return from east or north on .... track.
(u) — — — — o o	Flagman may return from west or south on .... track.
(v) — — — — — o o o	Flagman may return from east or north on .... track.
(w) — — — — o o o	Flagman may return from west or south on .... track.

*113. The explosion of two torpedoes is a signal to proceed at restricted speed. The explosion of one torpedo will indicate the same as two, but the use of two is required.

Torpedoes must not be placed at stations or on public crossings.

*114. The headlight will be displayed to the front of every train by night. It must be concealed or extinguished when a train turns out to meet another and has stopped clear of main track, or is standing to meet a train at end of two or more tracks or a junction.

It must be dimmed while passing through yards where yard engines are employed; approaching stations at which stops are to be made or where trains are receiving or discharging passengers; approaching train order signals, junctions, terminals, or meeting points or while standing on main track at meeting points and on two or more tracks when approaching trains in the opposite direction.

When an engine is running backward a white light must be displayed by night on the rear of the tender.

*115. Yard engines will display the headlight to the front and rear by night. When not provided with a headlight at the rear, a white light must be displayed. Yard engines will not display markers.

*116. The following signals will be displayed, to the rear of every train, as markers, to indicate the rear of the train: By day, yellow (or green) flags, or marker lamps (not lighted): By night, yellow (or green) lights to the front and side and red lights to the rear; except when the train is clear of the main track, when yellow (or green) lights must be displayed to the front, side and rear, and except when a train is turned out against the current of traffic, when yellow (or green) lights must be displayed to the front and side, a yellow (or green) light to the rear on the side next to the main track on which the current of traffic is in the direction the train is moving, and a red light to the rear on the opposite side.

*117. All sections except the last will display two green flags, and, in addition, two green lights by night, in the places provided for that purpose on the front of the engine.

*118. Extra trains will display two white flags and, in addition, two white lights by night, in the places provided for that purpose on the front of the engine.

*119. When two or more engines are coupled, each engine shall display the signals as prescribed in Rules 117, 118.

*120. One flag or light displayed where in Rules 116, 117 and 118 two are prescribed will indicate the same as two; but the proper display of all train signals is required.

*121. When cars are pushed by an engine, except when shifting or making up trains in yards, a white light must be displayed on the front of the leading car by night.

122. A blue signal, displayed at one or both ends of an engine, car or train, indicates that workmen are under or about it; when thus protected, it must not be coupled to or moved. Each class of workmen will display the blue signals and the same workmen are alone authorized to remove them. Other equipment must not be placed on the same track so as to intercept the view of the blue signals, without first notifying the workmen.

When emergency repair work is to be done under or about cars in a train and a blue signal is not available, the engineman and fireman will be notified and protection must be given those engaged in making the repairs.

USE OF SIGNALS

*150. A signal imperfectly displayed, or the absence of a signal at a place where a signal is usually shown, must be regarded as the most restrictive indication that can be given by that signal, except that when the day indication is plainly seen it will govern and when sufficient lights in the position-light signal are displayed to determine correct indication of signal, such indication will govern.

Conductors and enginemen using a switch where the switch light is imperfectly displayed or absent, must, if practicable, correct or replace the light.

Imperfectly displayed signals must be promptly reported to the ....

*151. A green and white signal will be used to stop a train only at the flag stations indicated on its schedule.

*152. When a signal, except a fixed signal, is given to stop a train, it must, unless otherwise provided, be acknowledged as prescribed by Rule 112 (g) or (h).

*153. The engine-bell must be rung when an engine is about to move and while approaching and passing public crossings at grade and ....,

*154. The whistle must be sounded at all places where required by rule or by law.

The unnecessary use of either the whistle or the bell is prohibited.

155. Watchmen stationed at public crossings at grade must use stop signals when necessary to stop trains. They will use .... signals to stop highway traffic.

*156. The following signals will be used by flagmen:

Day Signals—A red flag, torpedoes and fusees.

Night Signals—A red light, a white light, torpedoes and fusees.

*157. When a train stops under circumstances in which it may be overtaken by another train, the flagman must go back immediately with flagman's signals a sufficient distance to insure full protection, placing two torpedoes, and when necessary, in addition, displaying lighted fusees. When recalled and safety to the train will permit, he may return. When the conditions require he will leave the torpedoes and a lighted fusee.

The front of the train must be protected in the same way, when necessary, by the ....

When a train is moving under circumstances in which it may be overtaken by another train the flagman must take such action as may be necessary to insure full protection. By night, or by day when the view is obscured, lighted fusees must be thrown off at proper intervals.

When day signals cannot be plainly seen, owing to weather or other conditions, night signals must also be used.

Conductors and enginemen are responsible for the protection of their trains.

158. Motor, hand, velocipede and push cars, when in use, must be protected as prescribed by Rule 157.

RULES FOR THE GOVERNMENT OF EMPLOYEES WORKING ON OR ABOUT THE TRACK

200. It is the duty of employees working on or about the track to exercise care to avoid injury to themselves and others.

201. On the approach of a train, employees who are working on or about the track must move to a place of safety. They must not work or stand on the tracks, except when necessary for the proper performance of their duties.

202. Watchmen, patrolmen, trackwalkers and others on duty, which makes it necessary for them to be on the track, where there are two or more tracks, shall, when practicable, walk against the current of traffic, keeping sharp lookout in both directions for approaching trains.

203. Foremen or others in charge of employees, working on or about the tracks, must instruct their men to be alert, watchful, and to keep out of danger; and must take the necessary precautions to see that all men working under their immediate supervision receive warnings of approaching trains in time to reach a place of safety.

204. Foremen, watchmen and others in charge of gangs or squads of workmen, must provide themselves with a whistle and shall use same in warning the men of approaching trains, or when it is necessary for them to clear the tracks and move to a place of safety.

205. When large numbers of inexperienced men are working on the track, they must be divided into small squads, and each squad placed in charge of an experienced man, and such other additional precautions taken as will provide for the safety of the men.

206. In handling rails, ties and other heavy materials, special care must be used to avoid injury.

207. Employees working in or near the end of a tunnel, when a train approaches from either direction, must stand clear of all tracks, and if in the tunnel should occupy the refuge niches. If there is insufficient clearance or no refuge niches, arrangements must be made to work under flag protection.

208. Employees are required to carry lights when passing through any tunnel where men cannot readily be seen. When an entire gang is working close together, an adequate number of lights must be used, but not less than two.

209. Motor, hand, velocipede or push cars must not be used when approaching trains cannot readily be seen by reason of fog, storm or snow, except under proper protection.

210. Any employee, who while on duty, is careless about the safety of himself or others or who disregards warnings, shall be disciplined.

211. Foremen, watchmen and others in charge of gangs or squads of workmen, must consider it their individual duty to assist in keeping the tracks, yards and footpaths along them free of any obstacle which might cause injury to others.

RULES FOR THE GUIDANCE OF EMPLOYEES IN ELECTRIFIED TERRITORY

General

220. All wires and overhead conductors, third rail and conductors are to be considered alive at all times unless positive knowledge to the contrary is shown. Employees must not place dependence for their safety on the insulating covering of wires.

221. No unqualified employee shall do any work near overhead wires, third rail or apparatus unless a qualified employee is assigned to protect him against personal injury. When persons other than employees are required to do work near overhead wires or apparatus they must be protected by a qualified employee, who will take necessary precautions for their safety before starting and during the progress of the work.

222. When derricks are used in electrified territory the foreman in charge of the derrick must take special care to safeguard the workmen and himself from the electrified overhead wires. The operation of the derrick must be conducted under the personal supervision of the foreman and he must not allow any portion of the derrick or material to come within 5 feet of any of the overhead wires. Whenever the work cannot be handled in the manner above outlined the foreman must request the services of a qualified employee of the Electrical Department who will arrange to have the power cut off the overhead wires adjacent to the work.

223. Employees noticing dangling wires must avoid coming in contact with them. If energized they must so protect the wires that they will not endanger other persons and must correct the condition or promptly notify the proper authority.

224. Employees (excepting qualified employees authorized to do so in the discharge of their duties) are prohibited from going on top of box cars, locomotives, tenders or other high equipment while on tracks electrified with overhead wires or while movements are being made to such tracks from sidings, yards or other tracks which are not electrified.

225. Umbrellas, clothing and other material must not be placed where they may come in contact with switches or other portions of electric circuits.

226. When fire occurs near high voltage overhead wires or when fire apparatus is tested near live wires the power shall preferably be removed and the wires grounded. When this is not possible special nozzles with grounding jumpers securely attached must be used.

227. In case of an electrical fire, water must not be used to extinguish it. Sand, pyrene and other extinguishers containing tetrachloride of carbon may be used on electrical fires on arcs or other exposed live parts. The extinguishers containing tetrachloride of carbon must not be used in closed places due to danger of asphyxiation.

Transmission and Distribution Lines

235. Except in trouble and emergency work, no employee shall work alone dangerously near live lines of more than 750 volts in wet weather or at night.

236. Unless special precautions have been taken, employees working in the vicinity of live wires must remain at a safe distance, depending on voltage and local conditions.

237. Employees must not work in elevated positions unless secured from falling by a suitable safety belt or other adequate means.

238. No high tension disconnecting switch shall be operated except by means of the wood poles or other approved devices provided for that purpose.

239. Hand lines or measuring tapes containing metal strands must not be used.

240. When necessary to work on transmission lines, either aerial or underground, or any apparatus in connection therewith, the employees before doing so must notify the Power Director, giving him full information as to what work is necessary, location and length of time required.

241. If the section or apparatus on which work is to be performed may be de-energized, the Power Director will arrange for opening the necessary switches in the Power Stations and sub-stations affected, or on the line, will have them properly tagged and grounded at each disconnector opened for the protection of the employees and will then notify such employee that power has been shut off the section or apparatus. Before allowing men to work on such section or apparatus or before doing so himself, the said employee shall make out a permit on the prescribed form and repeat the information entered thereon to the Power Director, who will answer "correct" if the permit is properly made out. Said employee shall then see that all wires or apparatus upon which work is to be done are properly grounded at each side and near where the work is to be done, first making test according to prescribed methods to ascertain that apparatus is de-energized, not only at the source but also at point where work is being done, and if men are working with him caution them by calling their attention to any adjacent wires or fixtures that may be alive.

242. When necessary to ground lines or apparatus, grounding sticks of treated wood or other approved devices must be used, keeping the hands at a minimum designated distance from the circuits. This distance is dependent upon the circuit voltage and will be defined for each system. These grounding sticks are to be used only after power has been cut off the circuit and permission obtained to work thereon. Care must be taken to attach the ground wire to ground connection before placing other end in contact with the wire or apparatus on which work is to be done. In removing the ground wire it must be disconnected first from the wire or apparatus and then from the ground connection.

243. After work has been completed the employee who has obtained the clearance must assure himself that all men are clear and that grounds have been removed. He shall then personally notify the Power Director that the work has been completed, that all men are clear and that the wires and apparatus may be made alive. Power Director shall not have the circuits energized at the request of any other employee unless there is a definite understanding between the employee who has obtained the clearance and the Power Director that some other employee has been delegated to report "all in the clear."

244. All permits must be forwarded daily through prescribed channels to the proper officer.

245. When working on high voltage working conductor system, the employee shall see after current has been cut off that grounds are placed

on each side and near the point where work is to be done. He shall also ascertain from the Power Director that the line has been grounded at each disconnector opened for his protection. If work is to be done near a section break, on both sides of which the power has been cut off the trolley wire, he shall see that grounds are placed on each side of this section break.

246. In exceptional cases where physical and electrical conditions will permit and adequate safeguards are provided, authorized employees may perform work on overhead working conductors while alive.

Third Rail

250. When working on the third rail system the employee shall either see that the current is first cut off of the section on which work is to be done or shall take proper precautionary measures to avoid shock. Extreme care must be taken by all employees working in third rail territory.

251. Employees working on the track must be instructed previously on the dangers of the third rail and must use every precaution to avoid coming in contact with it or allowing any track tool to come in contact with the third rail.

Track Bonding

255. Loose connections to impedance bonds in the tracks must be regarded as alive and report promptly made to the Train Dispatcher.

256. All tracks carrying power current must be properly bonded to insure free flow of the current through the rail joints and bonds maintained in good condition at all times.

257. When one or more rails are removed, bonding must be done at time of renewal or in emergency, a jumper placed around joint until proper employees can be on hand to do the bonding.

RULES FOR THE OPERATION OF MOTOR, HAND, VELOCIPEDE AND PUSH CARS

260. Employees to whom cars are assigned are responsible for the proper use and condition of cars in their charge. A report must be made to their superior officer if the car is in need of repairs or is, in their opinion, unsafe to operate.

261. Cars must not be operated when known to be in unsafe condition.

262. No one except a responsible employee who has been qualified and authorized will be allowed to operate motor, hand or velocipede cars upon the main track.

263. Motor, hand and velocipede cars are to be used only for transporting workmen and tools. Heavy material must not be carried on them, except in emergency. Heavy materials, such as ties, rails, frogs, etc., must be transported by means of push cars.

264. Employees must not get on or off a moving car from the front or side. The use of seats on the ends of hand or push cars is prohibited.

265. Employees must not get on or off a moving car from the front or side. The use of seats not securely affixed to cars is prohibited.

266. Tools and material must be properly placed on cars to prevent their falling off. Track jacks must not be carried on the front end of the car.

267. Employees operating cars on main tracks shall, when practicable, obtain information regarding trains, but such information will not relieve them from responsibility of protecting their cars. They will see that their cars are clear of the main track for regular scheduled trains and, when blocked by an operator or the dispatcher, must report clear when out of the block or clear of the main track. Cars must be operated with the expectation of finding the main track in use and care exercised to avoid striking other cars.

268. Where practicable, cars must be run on outside main tracks in the direction of traffic or on sidings. A sharp lookout must be maintained in both directions, and where the vision is obscured or impaired, flagging rules must be observed.

269. When approaching workmen on or near track, or when approaching road crossings at grade, the car must be under complete control or stopped, and the employee in charge must know that the workmen or highway traveler will not be endangered before proceeding. If the crossing is protected by flagman, the operator must get signal from him before proceeding. When required by rule or law, a proper warning must be given when approaching highway crossings at grade.

270. Cars must not exceed a speed of *8 miles per hour* when passing through stations or yards, over switches or through interlocking, over frogs, railroad, highway or farm crossings at grade. At all other points, hand cars are restricted to *10 miles per hour* and motor cars to *20 miles per hour*. Cars must be stopped, when practicable, during passage of a train on an adjacent track.

271. Cars must be operated with care in passing trains receiving or discharging passengers at stations and must not be run between such trains and the station.

272. Motor cars must not be run through the spring rail side of frogs. Main track switches must not be opened to use siding for cars except when loaded too heavy to lift over the rails. When necessary to open the switch for a loaded car, the employee in charge of the car must personally unlock and lock the switch, as provided in Rule 26.

273. Cars must not be attached to engines or trains and they must not be run closer than 500 feet behind moving trains nor stopped within 200 feet of standing trains.

274. Unless coupled, space between two or three cars when running must not be less than 500 feet. A car in advance must not be stopped until the following car has been signaled. The employee in charge of two or three cars so run must ride on the second car. When more than three cars are run, they must be divided into groups of three or less, the front car of each group being run not less than 1200 feet behind the last car of the preceding group, and each group being run as specified above.

275. When motor, hand, velocipede or push cars are operated at night or during fogs, storms, snow or through tunnels, they must be equipped with a white light in front and a red light to the rear.

276. Cars must be removed from the track or protected by flag when not in use. When they cannot be removed from the track to clear an approaching train, they must be protected as required by Rule 157.

277. A copy of the current timetable must be carried on all hand and motor cars and, in addition, the following signal equipment:

— torpedoes
2 red flags
2 red lanterns
2 white lanterns
— fusees

278. Torpedoes exploded by motor, hand, velocipede or push cars must be replaced.

279. Cars must not be overloaded. Brakes must be applied gradually and emergency stops made only when absolutely necessary.

280. Hand and push cars should not be run with motor cars, but if necessary to do so, they must be coupled behind and never pushed ahead. When hand or push cars are coupled, the speed of the motor car must be reduced to the maximum speed provided for hand cars in Rule 270.

281. Employees in charge of motor cars must not permit occupants to sit in insecure or careless positions, nor permit any smoking or uncovered lights around motor cars when tanks are being filled or gasoline handled. Motor cars must not be inspected with matches or torches. All moving parts must be guarded.

282. When necessary to ship motor cars on train, gasoline tanks and carburetors must be drained.

283. Only insulated cars shall be used where there are track circuits.

284. When cars are removed from the track they must be placed not less than five feet from the near rail, and so located that they cannot foul the track. They must not be set off or left standing within the full legal width of highway or private road crossing at grade, except in cases of emergency. When necessary, on account of emergency, in clearing trains, cars may be set off at crossings but must be protected by an employee and immediately removed when the emergency is passed. They must be kept locked when not in sight of the men in charge, and, at night, and at other times, when not in use, must be kept under cover.

RULES FOR THE CARE OF MOTOR CARS

285. An employee, in order to properly qualify himself to operate a motor car, must thoroughly understand the complete cycle of operation of the engine, study the printed booklet of instructions furnished by the maker, and acquaint himself with the gasoline circuit, the electric equipment and circuit, the methods of lubrication, and the proper methods of starting and stopping the engine and car.

286. Motor cars must be inspected carefully before starting to detect loose or broken parts and to see that the wheels are in proper alinement. When running, attention must be given to any unusual noise about the engine or car, and the car must be stopped and adjusted before proceeding. In making long runs the car must be stopped periodically and examined for overheated parts or bearings and to insure proper lubrication.

287. Motor cars must be thoroughly cleaned and all bolts and nuts tightened at least once each week. A thorough inspection of all parts must be made when car is overhauled or cleaned.

288. Engine must not be raced or left running when the car is standing.

289. All wearing parts and bearings of engine and car must be kept properly lubricated. When lubricated gasoline is used, it must be properly proportioned and mixed before placing in the fuel tank.

290. In case of motors having water cooling systems, water tanks and radiators or jackets must be kept properly filled, and during freezing temperatures they must be protected against freezing or the water drained when not in use.

291. More than the required number of dry cell batteries must not be used. Spark coil vibrator must be kept clean and properly adjusted. Spark plugs must be kept clean and free from carbon. Timers must be kept clean, well oiled and in proper adjustment. Wiring must be properly insulated and connections kept tight.

292. To secure the lowest maintenance and highest efficiency of the engine, the carburetor must be adjusted by a competent man and must not be tampered with. Gas line must be kept free from stoppage and leaks immediately repaired.

293. In case of belt driven cars, tension on belts must not be excessive. In the case of friction disk drive, the disk must be kept clean and dry and free from oil.

294. Extreme care must be exercised in the handling of gasoline, and gasoline should preferably be stored in tanks removed from the motor car house. Gasoline must be strained before placing in fuel tank. Fuel tank, oil cans and funnels must be kept clean.

295. The employee in charge of motor car will be furnished with proper complement of required tools and will be responsible for their use and care.

296. Care must be exercised in placing motor car on or off the track and in loading or unloading tools, to avoid disturbing the adjustment of engine or damage to engine or car.

297. If car is started with a crank, it must be pulled upward holding thumb against forefinger when the charge is being compressed in the cylinder, to avoid injury to the person cranking the car in case the engine should backfire.

ORGANIZATION

TITLES OF RANK OF DIVISION ENGINEER AND BELOW, TO DESIGNATE POSITIONS OF CORRESPONDING RANK IN MAINTENANCE OF WAY SERVICE

Division Engineer is title of chief maintenance officer on Division.

Supervisor of Bridges and Buildings is the title assigned to the supervisory officer responsible for maintenance of bridges, buildings and structures.

Supervisor of Water Service is the title assigned to the supervisory officer responsible for maintenance of water service.

Supervisor of Signals is the title assigned to the supervisory officer responsible for maintenance of signals.

Supervisor of Telegraph and Telephones is the title assigned to the supervisory officer responsible for maintenance of telegraph and telephones.

Supervisor of Track is the title assigned to the supervisory officer responsible for maintenance of track.

Supervisor of Work Equipment is the title assigned to the supervisory officer responsible for work equipment.

*These subordinate divisional officers, in their respective departments, have foremen and others reporting to them, the Foreman being usually the officer under whose immediate supervision the skilled and unskilled laborers perform their work.

DUTIES OF DIVISION OFFICERS

Division Engineers

300. Division Engineers report to and receive instructions from the ....

301. They are responsible on their respective divisions for such Maintenance of Way matters as are assigned them. They will have supervision over the employees in their department, see that they understand and obey the rules and regulations in force, and that the work is carried on in a proper, careful and economical manner; that records of time and material are correctly and properly kept, and that the necessary and prescribed reports, covering the time worked and the material used, are promptly and properly made.

Supervisors of Track

305. Supervisors of Track report to and receive instructions from the Division Engineer.

306. They are in charge, in their respective districts, of the maintenance of tracks, their appurtenances and of the employees engaged thereon.

307. They will have immediate supervision of work train service for the maintenance of tracks, using such service only when properly authorized by the Division Engineer.

308. They must make the prescribed inspection of track, roadway, station grounds, and driveways under their charge, and when necessary arrange for prompt repairs of any defects or improper conditions found.

309. They must know that Foremen, track laborers and others under their supervision fully understand and properly perform their duties; keep account of, and report their time in the manner prescribed and discipline them when necessary.

310. They must know that Foremen are supplied with tools and material necessary for the efficient performance of their duties and that these are properly used.

311. They must keep themselves informed in regard to all work performed upon tracks and roadway in their districts by contractors or others, who may not be under their supervision; see that the work is done in such

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*Titles for these officers not yet submitted.

a way as not to endanger the safety of tracks or roadway and report promptly to the proper officer, if the work is not being done in accordance with the plans and specifications or according to prescribed standards.

312. In case of damage to tracks or roadway, they must promptly assemble men and material, proceed to the place of accident as quickly as possible and make the necessary repairs. They must investigate all accidents to track and roadway and report promptly to the proper officer on the prescribed form.

313. They must know that the vicinity of all bridges and trestles is clear of combustible matter; that the bridge seats, tops of the piers and other readily accessible portions of bridges and trestles are clear of cinders and dirt, and that the water barrels are kept full of water.

314. They must know that the waterways and the approaches and outlets thereto are free from obstructions.

315. They must not permit encroachment upon or occupancy of any portion of the Company's buildings, right-of-way or station grounds, except upon proper authority.

SECTION FOREMEN

325. Section Foremen report to and receive instructions from the Supervisor of Track.

326. Section Foremen are in charge of and responsible for the safe condition of tracks, roadway and right-of-way on their sections, and for the economical use of labor and material in their maintenance. They must do no work thereon that will interfere with the safe passage of trains, except under proper protection.

327. Section Foremen must go over their sections or send a competent reliable man with suitable tools, at designated intervals, to make a thorough inspection, and see that the track, culverts, highway crossings, bridges, fences, etc., are in safe condition. If, in their judgment, the track or any bridge or culvert is not safe, they must at once put out proper signals to warn approaching trains, notify the Supervisor of Track, Division Engineer and Superintendent of the condition and do everything in their power to make the necessary repairs.

328. Section Foremen will have full charge of all forces under them, and shall employ the number of men the Supervisor of Track directs. They must see that employees properly perform their duties, and shall discipline those who are incompetent or neglectful. They must keep the records and make the prescribed reports of the time of their men, and of the receipt, distribution and use of the material furnished them.

329. In case of accident, Section Foremen must immediately proceed to the scene and render all assistance in their power, whether the accident occurs on their own or a neighboring section.

In the absence of the Supervisor or other ranking officer, the Section Foreman on whose section the accident occurs, will have charge of the assembled track forces, and shall be responsible for the character of the repairs made. He must not allow the track to be used until it is known to be safe.

330. Section Foremen must investigate all accidents resulting in derailment or in damage to the track, roadway, or structures on their sections, and

report on the prescribed form, giving the cause, as nearly as they are able to ascertain it.

331. They must keep themselves informed in regard to work performed on their sections by contractors or others who do not come under their charge, and see that nothing is done by them that will interfere with the safety of tracks or the safe passage of trains.

332. They must make a personal inspection of their sections at designed intervals, examining particularly main track switches and frogs, looking for concealed defects or breaks.

333. They must give special attention to points where obstructions are likely to occur, examine the slopes of cuts, and promptly remove all earth, trees, rocks, or anything likely to fall or slide upon the track, reporting such conditions to the Supervisor of Track.

334. Section Foremen must maintain surface ditches in such a manner that the surface water is carried beyond the cut.

335. Section Foremen must keep the ditches and waterways leading to and from bridges and culverts clear within the limits of the right-of-way. They must remove accumulated drift and obstructions from trestles, culverts and bridges after each storm, calling for assistance when needed.

336. During heavy storms or high water, whether by day or night, whereby tracks or structures are liable to be damaged, Section Foremen and such of their forces as they deem necessary, must be on duty. At such times, they must go over their sections to make sure that the track is safe, taking stop signals with them.

337. They must see that watchmen are properly detailed to patrol the track, watch bridges or perform other duties, whenever necessary, for the safety of track and structures.

338. They must keep a careful lookout for fires along the track, and prevent, if possible, the destruction of buildings, fences, telegraph poles, timber, or other material, and the spread of fires to adjoining property. They must not permit fires to be started unless they have sufficient force to keep them under control.

Fires discovered on adjoining property must be promptly extinguished, if possible, and a report of the damage and origin, if it can be ascertained, made on the prescribed form.

339. They must keep the ground under and near buildings, bridges and trestles cleared of vegetation and combustible matter. Where water barrels are in use, they must keep them filled with water. They must keep bridge seats, tops of piers, and other readily accessible portions of bridges and trestles free from cinders, dirt and vegetation.

340. They must keep interlocking pipe lines and trunking free from grass and weeds; switches, frogs and movable parts of interlocking plants must be kept free from snow, ice and other obstructions. They must give special attention to drainage through interlocking plants and where track circuits are used.

341. When track work is to be done which may disturb interlocking or signal apparatus, there must be co-operation between the Section Foreman and the Signal Maintainer or Foreman.

342. They must give special attention to the maintenance of road crossings, both as to safety and quality of track and as to the safe and

comfortable accommodation of the highway travel on the crossing and approaches.

343. They must not permit any encroachment upon the Company's property or occupancy of any portion of the Company's buildings or grounds without proper authority.

EXTRA OR FLOATING GANG FOREMEN

350. Extra or Floating Gang Foremen, in charge of trackmen, report to and receive instructions from the Supervisor of Track.

351. They will have full charge of all forces under them, perform such duties and employ the number of men the Supervisor of Track directs.

WATCHMEN

355. Track, Bridge* and Tunnel Watchmen report to and receive instructions from the Section Foremen.

356. Track Watchmen must carefully examine the track and roadbed and see that they are in safe condition and that all switches are properly set and locked for the main track. They must examine buildings and other property of the Company and protect them from theft and fire. Should the track be obstructed, the Watchmen must display stop signals in either direction from which trains may approach, and immediately notify the .... and the Section Foreman.

357. Bridge Watchmen must keep a supply of water or sand on the bridges at all times and be prepared to extinguish fires. They shall keep the coping of the abutments and piers clean, remove combustible materials from near the bridges and frequently examine them and report any defects found. Should they observe any obstruction of a dangerous character, they must display stop signals in either direction from which trains may approach, and immediately notify the ....

358. Tunnel Watchmen must make frequent trips through the tunnels, observing the condition of the tracks, particularly the rails, and also observe the walls of the tunnel, removing in winter all icicles which may become dangerous to traffic. In case obstructions occur which would endanger trains, they must at once display stop signals in either direction from which trains may approach and immediately notify the ....

359. When the time of Track, Bridge or Tunnel Watchmen is not fully occupied with watching, they shall perform such other duties as may be assigned them.

SUPERVISORS OF BRIDGES AND BUILDINGS

365. Supervisors of Bridges and Buildings report to and receive instructions from the Division Engineer.

366. They are in charge, on their respective districts, of the maintenance of bridges and structures, and of the employees engaged thereon.

367. They shall have immediate supervision of work train service for the maintenance of bridges and structures, using such service only when properly authorized by the Division Engineer.

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*Refers to watchmen patrolling bridges, not to structure watchmen.

368. Supervisors of Bridges and Buildings must make the prescribed inspections of the structures and appliances under their charge, and make the required reports.

369. They must know that the Foremen and others under their supervision fully understand and properly perform their duties; keep account of and report their time in the manner prescribed and discipline them when necessary.

370. They must know that the Foremen are supplied with tools and material necessary for the efficient performance of their duties and that these are properly used.

371. They must keep themselves informed in regard to all work performed upon bridges and structures in their districts by contractors, or others, who may not be under their supervision; see that the work is done in such manner as not to endanger the safety of tracks, bridges or structures, and report promptly to the proper officer, if the work is not being done in accordance with the plans and specifications or according to prescribed standards.

372. In case of damage to bridges or structures they must promptly assemble men and material, proceed to the place of accident as quickly as possible, and make necessary repairs. They must investigate all accidents to bridges and structures, and report promptly to the proper officer on the prescribed form.

373. They must know that water barrel or sand box rests on all timber bridges and trestles are in repair and supplied with barrels and buckets, and that station and other structures are equipped with the necessary water barrels, buckets and other appliances for use in case of fire.

General Foremen

380. General Foremen in the Bridge or Building Department report to and receive instructions from the Supervisor of Bridges and Buildings. All rules for the guidance of Supervisors of Bridges and Buildings apply to General Foremen in that Department.

381. They will have charge, under the Supervisor of Bridges and Buildings, of all bridges and structures in their respective districts; will have general oversight of the work being performed on such bridges and structures, and will perform such other duties as may be assigned them by the Supervisor.

Bridge and Building Foremen

385. Bridge and Building Foremen report to and receive instructions from the Supervisor of Bridges and Buildings.

386. They are responsible for the safe, proper and economical performance of the work assigned to them. They must do no work on a bridge or structure which will interfere with the safety of trains, except under proper protection.

387. They will have full charge of all forces under them and shall employ such forces as the Supervisor of Bridges and Buildings directs. They must see that employees properly perform their duties, and shall discipline those who are incompetent or neglectful. They must keep the

records and make the prescribed reports of the time of their men, and of the receipt, distribution, and use of material furnished them.

388. They will have charge of and are responsible for such tools and materials as are necessary for the performance of their work, and must know that these are properly used.

389. They must, upon completion of any work, clean the premises of any debris and make proper disposition of usable materials.

Mason Foremen

395. Mason Foremen report to and receive instructions from the Supervisor of Bridges and Buildings.

396. They are responsible for the safe, proper and economical performance of the work assigned to them. They must do no work on a bridge or structure which will interfere with the safety of trains, except under proper protection.

397. They will have full charge of all forces under them and shall employ such forces as the Supervisor of Bridges and Buildings directs. They must see that these men properly perform their duties, and shall discipline those who are incompetent or neglectful. They must keep the records and make the required reports of the time of their men, and of the receipt, distribution and use of material furnished them.

398. They will have charge of and are responsible for such tools and materials as are necessary for the performance of their work, and must know that the tools and material are properly used.

399. They must, upon the completion of any work, clean the premises of any debris, and make proper disposition of usable materials.

Painter Foremen

405. Painter Foremen report to and receive instructions from the Supervisor of Bridges and Buildings.

406. They are responsible for the safe, proper and economical performance of the work assigned to them. They must do no work on bridges or structures which will interfere with the safety of trains except under proper protection.

407. They will have full charge of all forces under them and shall employ such forces as the Supervisor of Bridges and Buildings directs. They must see that their men properly perform their duties and shall discipline those who are incompetent or neglectful. They must keep the records and make the prescribed reports of the time of their men, and of the receipt, distribution and use of material furnished them.

408. They will have charge of and are responsible for such tools and materials as are necessary for the performance of their work, and must know that these are properly used.

409. Painter Foremen must examine the rigging and exercise care in the erection of rigging and scaffolding, and must know that they are safe before permitting them to be used.

410. They must, upon the competion of any work, clean the premises of any debris, and make proper disposition of usable materials.

SUPERVISORS OF WATER SERVICE

420. Supervisors of Water Service report jointly to the Division Engineer, and the Superintendent or Engineer of Water Service.

421. They are responsible for all matters pertaining to water service on the local division and may also have charge of the plumbing and heating facilities of all buildings.

422. They will have charge of Water Service or Gang Foremen, Repairmen and Pumpers.

WATER SERVICE REPAIRMEN OR GANG FOREMEN

431. They will be responsible for the safe, proper and economical performance of work assigned to them. They must do no work which will interfere with the safety of trains, except under proper protection.

436. In connection with their regular duties, they must prevent unless otherwise directed, water waste, and see that all valves are properly maintained and used so as to avoid waste; they must also check water bills and read water meters.

430. Water Service Repairmen or Gang Foremen report to and receive instructions from the Supervisor of Water Service.

432. They will have immediate charge of helpers, laborers and all other forces under them and will exercise general supervision over pumpers on their districts or assigned territory. They must keep such records as the Supervisor of Water Service may direct and make the required reports of work done and of the receipt, distribution and use of material furnished them.

433. They will have charge of and be responsible for the proper maintenance of water stations, including wells, pipe lines, tanks, water columns, heating plants, windmills and other facilities used in connection therewith. They will be responsible for the maintenance of plumbing, heating and such other facilities as the Supervisor of Water Service may designate. They will be responsible for the proper maintenance of fire pumps, hydrants, hose and other facilities required for protection against fire (exclusive of fire extinguishers, water barrels and buckets) except at locomotive terminals where fire protection facilities are handled by the Mechanical Department.

434. They will have charge of and be responsible for such tools and materials as are necessary for the performance of their work and must know that these are properly used. They must advise the Supervisor of Water Service of the necessity for materials well in advance of the actual need.

435. When necessary to take out of service any water tank, water column or other facilities affecting the water supply or the operation of any other department, either temporarily or permanently, repairmen will notify the Supervisor of Water Service and must not—except in emergency—proceed with the work until the proper authority is obtained. If an emergency exists, they must notify the Supervisor of Water Service and Chief Dispatcher by wire. Proper notice must be given when the facility is restored to service.

437. They must at all times keep the Supervisor of Water Service and Chief Dispatcher advised of their movements so that they may be available in case of an emergency.

PUMPERS

450. Pumpers report to and receive instructions from the Supervisor of Water Service.

451. Pumpers will be in charge of the local water supply and will be responsible for the general condition of the entire plant. Their first duty is to see that an ample supply of water for locomotive use is available at all times.

452. In case of trouble affecting the water supply, pumpers must wire the Chief Dispatcher as well as the Supervisor of Water Service stating fully the difficulty, what is needed for repairs, and approximately how much water remains on hand. They must make frequent inspection of all parts of the plant, make all repairs within their power and avoid sending for Repairmen except when absolutely necessary. They will be responsible for the safe keeping and the economical use of supplies furnished and also place requisitions for fuel and other supplies in ample time to avoid a shutdown of the plant.

453. In freezing weather, they must see that all parts which are liable to freeze, are drained.

454. Conditions which may affect the quality of the water or which may affect the supply at the source must be immediately reported to the Supervisor of Water Service. Coal and cinders must not be dumped where they are likely to affect the quality of the water supply.

455. Pumpers shall keep such records on prescribed forms as may be required by the Superintendent or Engineer Water Service.

456. Pump houses must be kept neat and clean and every precaution taken against loss or damage by fire. Waste or other combustible material, if necessarily stored in pump houses, must be kept in iron receptacles, having suitable covers. The station supply of oil and gasoline must be stored outside the building in proper receptacles.

457. The machinery must be inspected daily and adjustment made to maintain efficiency and to prevent undue wear or a possible breakdown. Particular attention must be given to the packing and lubricating of all parts. Pumpers must be familiar with the location and the purpose of all steam and water pipes, valves, levers, etc., so that in case of accident or leaks the controlling valves may be properly used. They must also be thoroughly familiar with the proper care and the operation of the steam plant, the internal combustion engine or the electric motor which may be used for the operation of the pumping machinery.

458. Pumpers will keep a daily record of water pumped and, if at a treating plant, a record of the chemicals used each day. They shall, as far as practicable, watch the operation of water columns or other facilities at their station and promptly report any defects. If employees do not properly handle such facilities the facts should be promptly reported, together with engine number, date and time.

MOTOR CAR MAINTAINERS

470. Motor car maintainers report to and receive instructions from the ....

471. They will instruct all operators of motor cars, portable air compressors, or other gasoline engines in the operation and care of the machines.

472. They must inspect all such machines at regular intervals and make such repairs as can be made in the field.

473. They must keep the stock of repair parts replenished in accordance with standard list.

474. They must personally see before a new device is put in service that the operator has a proper understanding of the operation of his machine.

475. They must see that forms covering cost and performance reports are properly kept by the operators of the machines.

SUPERVISORS OF WORK EQUIPMENT

490. Supervisors of Work Equipment report to and receive instructions from the Division Engineer.

491. They will be in charge, on their respective divisions, of such work equipment as may be under the general supervision of the Division Engineer.

492. They must report their movements daily to the Division Engineer and Chief Dispatcher.

493. They will be responsible for the operation and maintenance of all equipment while under their charge.

494. They must see that the repairmen are properly equipped with tools and supplies, that they perform their work efficiently and make proper reports.

495. They must make a quarterly inspection of all work equipment, reporting on the prescribed form to the Division Engineer, stating the condition and when repairs will be necessary.

496. They must make a monthly report of the performance of work equipment under their jurisdiction, giving amount of work accomplished, cost of fuel, lubricants and other supplies necessary to run the machines and cost of repairs.

497. Division Engineer must be notified when necessary to take any work equipment out of service. Prompt notice must be given when again ready for service.

498. They will keep daily record of locations of each machine, together with such records of performance as are necessary to make the required reports.

499. They must see that Work Equipment Repairmen and Operators make the required reports on the cost of repairs and operation of the machines under their charge.

WORK EQUIPMENT REPAIRMEN

505. Work Equipment Repairmen report to and receive instructions from the Supervisor of Work Equipment.

506. They will have immediate charge of helpers, laborers and all other force under them engaged in the maintenance of work equipment.

507. They will keep such records regarding the cost of repairs to work equipment and other roadway machines as the Supervisor may direct and make the required reports of work done and of the receipt, distribution and use of material.

508. They will have charge of and be responsible for the proper maintenance of all work equipment and roadway machines on their assigned territory.

509. They must know the exact condition of work equipment and roadway machines under their jurisdiction, making inspection of them at every available opportunity.

510. They will have charge of and be responsible for such tools and material as are necessary for the performance of their work and must know that these are properly used.

511. Work equipment and roadway machines, including motor cars, must not be shipped to the equipment shop for repairs unless repairs are of such nature that they cannot be performed economically in the field.

512. Equipment in unsafe condition must not be permitted to remain in service.

Work Equipment Operators

515. Work Equipment Operators report to and receive instructions from the Supervisor of Work Equipment.

516. They will have charge of any helpers assigned to their machine.

517. They will make the required reports covering the operation of the machine as the Supervisor of Work Equipment may direct and will forward them as instructed.

518. They must know the exact condition of the machine under their charge; that it is in proper condition to do the work efficiently, and if, in their judgment, such machine is not performing efficiently, they must notify the Supervisor, in detail, wherein such machine is not in condition.

519. They will have charge of such tools and equipment as may be assigned to them and if any such tools are not in proper condition, must notify the Supervisor of Work Equipment.

520. They must not ship machine to shop for repairs except upon proper authority from the Supervisor of Work Equipment, but when such machine is forwarded, they must see that it is properly prepared for safe movement and in case an operator does not accompany the machine, all brass and other valuable parts, easily removable, should be taken off, boxed and shipped separately.

Supervisors of Signals

(A Rule preceded by a † is a rule of the Signal Section, American Railway Association.)

†530. Supervisors of Signals report to and receive instructions from the Division Engineer.

†531. They will be responsible for the safe condition and proper maintenance of signals and interlocking plants and shall perform such other duties as may be assigned to them.

†532. They must make frequent inspections of signals and interlocking plants and have necessary repairs made as promptly as conditions require. They must see that all failures of signals and interlocking plants are properly investigated and report made on proper form.

†533. They shall, as necessary, employ men for carrying out the duties for which they are responsible.

†534. They must know that Foremen are supplied with tools and material necessary for the efficient performance of their duties, and see that these are properly used and cared for.

†535. They must keep themselves informed in regard to all work performed on their district by contractors, or others who do not come under their charge, so that nothing is done by them that will interfere with the safe operation of signals and report promptly to the Division Engineer, if the work is not done in accordance with prescribed standards.

†536. They must, in case of damage to signals or interlocking, promptly assemble forces, tools and material to make necessary repairs.

†537. They must investigate and report on accidents which may be attributable to defects in, or result in damage to the signal apparatus.

†538. They will have immediate supervision of work train service for the maintenance of signals and interlocking plants in their districts and employ such service only when authorized by the Division Engineer.

539. They must not make or permit to be made any alterations or additions to the interlocking or signal apparatus without proper authority. Such authorized changes or additions as are made must be reported to the proper authority immediately upon their completion, so that the other departments affected may have such information.

†540. They must know that the Foremen are provided with the rules, circulars, forms and special instructions pertaining to their duties and that they fully understand and comply with them.

Signal Foremen

†550. Signal Foremen report to and receive instructions from the Supervisor of Signals.

†551. They will be responsible for the proper installation and safe condition of signals and interlocking plants under their charge, and must do no work thereon that will interfere with the safe passage of trains, except under proper protection.

552. They shall employ men as the Supervisor of Signals directs. They must treat employees with consideration, and see that they properly perform their duties. They must discharge men who are incompetent or neglect their duties, but in no case shall they discharge men without cause. They must keep the required records of the time of their men and of material used.

†553. They will be responsible for the proper care and use of tools and materials necessary for the efficient performance of their duties, and shall make requisition to the Supervisor of Signals from time to time as additional supply becomes necessary.

554. When any part of an interlocking plant is to be repaired, an understanding must be reached with the signalman on duty, in order to insure safe movement of trains and engines during repairs. The signalman on duty must be notified when the repairs are completed.

555. Signal Foremen must notify the Supervisor of Signals, in advance of any work requiring the removal from service of any part of signal or interlocking apparatus, and such apparatus must not be taken out of service until proper authority is obtained.

556. They must, upon the completion of any work, clean the premises of any debris, and make proper disposition of usable materials.

SIGNAL MAINTAINERS

560. Signal Maintainers report to and receive instructions from the Supervisor of Signals.

†561. Maintainers are responsible for the inspection, adjustment and proper maintenance of signal and other apparatus assigned to their care.

†562. Maintainers must personally instruct their subordinates with a view to safety, efficiency and economy.

†563. An assistant maintainer in the absence of a maintainer will consider himself in charge, unless a substitute has been provided. He must open all railroad mail addressed to the maintainer and perform all the latter's duties.

†564. Maintainers must systematize their work, performing certain duties on certain days in orderly sequence, consulting the Supervisor of Signals as to the most efficient system to be followed.

565. Maintainers will have full charge of such forces as the Supervisor of Signals directs. They must see that these men properly perform their duties. They must keep the records and make the required reports of the time of their men, and of the receipt, distribution and use of the material furnished them.

†566. Maintenance forces shall have correct plans of all work under their care. These must be kept in good order and where they will be available when required.

†567. Alterations or additions must not be made unless authorized by the Supervisor of Signals.

†568. Apparatus must not be taken out of service without proper authority, except for immediate replacement or in case of emergency, when the Supervisor of Signals must be notified promptly.

†569. Tool houses, signal stations, signal appliances, etc., must be kept clean and surroundings free from rubbish and weeds. If this is not done, the proper official must be notified. Inflammable material must not be stored in, against or under buildings unless provisions are made for safe storage of same.

†570. Scrap and salvage material must be collected at headquarters and shipped in accordance with instructions.

†571. Material must be stored in a place provided for that purpose.

†572. Material delivered on the line must be neatly arranged and small parts properly secured from theft.

†573. Housing, containing signal appliances, must be kept securely locked.

†574. When inspecting a signal station, check emergency tools, and if any are missing, see that they are immediately replaced and report to the Supervisor of Signals.

†575. Proper tools, in condition for immediate use, must be kept on hand at all times. A report of tools on hand must be made to the Supervisor of Signals, when required, or whenever transferred or promoted.

†576. Electrical measuring instruments must be handled with extreme care. Shipping instructions for damaged instruments will be furnished by the Supervisor of Signals on request.

†577. Employees must be on the alert to detect defects in maintenance, design, manufacture and installation of apparatus under their care. No

chances shall be taken with defective material, but it must be promptly replaced with material in perfect condition and full report made to the Supervisor of Signals in writing.

578. When any part of an interlocking plant is to undergo repairs, an understanding must be reached with the signalman on duty, in order to insure safe movement of trains and engines during repairs. If it is necessary to disconnect any switch, movable-point frog or derail, it must be safely secured in proper position before permitting trains or engines to pass over it.

579. Signal Maintainers must notify the Supervisor of Signals before taking any signal or interlocking apparatus out of service, and authority must be obtained, except in emergency, before such apparatus is taken out of service. Should an emergency arise which requires removal from service of any apparatus, signals must display their most restrictive indication; switches, movable-point frogs and derails must be safely secured in correct position and Supervisor of Signals, Division Engineer and Superintendent immediately notified by wire.

†580. In case of severe storms, maintainers must go to any points on their territory where they feel that trouble is likely to occur, keeping in touch with the telegraph office so that they will be available in case of trouble elsewhere.

†581. After a heavy wind storm, pole line, signal blades and other signal apparatus subject to damage, must be inspected.

†582. In case of severe electrical storms, inspection must be made as soon as storms cease, and any cases of trouble cleared by replacing or repairing damaged electrical apparatus.

†583. In case of snow or sleet storm, interlocking plants must be watched carefully to see that switches, pipe lines, etc., are kept clean and in operation; that the leverman observes rules requiring him to operate levers from time to time to keep them from freezing, and that sufficient forces are available to keep switches, etc., free from obstruction. Remove snow and ice from signal blades, roundels and other movable parts where it might prevent proper operation or indication of apparatus.

584. In case of accident or serious damage to interlocking or signal apparatus in their territory, Signal Maintainers must immediately proceed to the place, asking for such assistance and material as may be required, and make repairs promptly.

585. Failures must be given preference over all other work in the following order:

(a) Improper proceed signal.
(b) Highway crossing device failing to indicate approaching trains.
(c) Improper clear indicator.
(d) Electrical and mechanical locking devices failing to function so as to provide safety for the movement of trains.
(e) Single track automatic signals failing to assume a proceed indication.
(f) Interruptions at interlocking plants.
(g) Other failures.

†586. A thorough investigation must be made of every reported failure and the trouble must not be reported as due to a cause which is only sus-

pected. In all cases an endeavor must be made to definitely determine the trouble and eliminate the true cause.

†587. In all cases of failure, damage, or other irregularities, a brief report must be forwarded promptly to the Supervisor of Signals, stating cause, nature and extent of damage and time repairs were completed. As soon as possible after repairs have been completed, Signal Maintainer must render proper report and forward same to the Supervisor of Signals with the least possible delay, retaining copy for reference.

†588. Temporary repairs or adjustments must not be made except when permanent work cannot be finished promptly. Permanent repairs or adjustments must be made as soon thereafter as possible.

†589. If an accident may have been caused, or is alleged to have been caused, by defects in the signal apparatus, a thorough examination must be made immediately of all parts involved, and telegraphic report sent at once to the Supervisor of Signals.

†590. Signal Maintainers must co-operate with track forces in joint track and signal work, to see that signal apparatus is maintained in proper condition.

591. Signal Maintainers must make such inspection and repairs of signal apparatus under their charge as will secure proper operation. They must inspect the signal lights on their territories at regular intervals and make report to the Supervisor of Signals.

†592. Until proper protection is provided, a switch in signal territory must be securely spiked, and signals secured so as to display their most restrictive indication.

†593. If track is found to be unsafe for trains, due to broken rail, wide gage or other causes signals must be secured to display their most restrictive indication and immediate steps taken to protect trains by flag, notifying section foremen and proper officials so that the defect may be remedied as quickly as possible.

†594. Frequent inspection and tests must be made to insure that all signal appliances, including machine locking, etc., are kept in proper condition.

DUTIES OF TELEGRAPH AND TELEPHONE OFFICERS

(Rules with reference to Telegraph and Telephone employees were prepared by the Telegraph and Telephone Section and approved by the A.R.A.)

General Foremen of Telegraph and Telephone

600. The General Foremen of Telegraph and Telephone shall report to and receive instructions from the Superintendent of Telegraph and Telephone. They shall supervise the construction and maintenance of all telegraph and telephone pole lines, wires and their appurtenances and such equipment work as may be assigned to Telegraph and Telephone Maintainers—Section Linemen.

601. When a pole line is to be totally reconstructed or poles required to be moved, the location of such pole line, or of fixtures on bridges and structures, must be as indicated by the proper officer.

602. They must make frequent inspection of all telegraph and telephone pole lines, wires, appurtenances and equipment under their charge and make the required reports.

603. They must know that Foremen, Maintainers and others, under their supervision, fully understand and properly perform their duties, keep account of and report their time in the manner prescribed and administer discipline when necessary.

604. They must know that Foremen and Maintainers are supplied with tools and material necessary for the efficient performance of their duties and that they are properly used.

605. They must keep themselves informed in regard to all work being performed by contractors or others, who may not be under their supervision, which might affect the telegraph and telephone plant and report to the proper officer if the work is being done in such a way as to endanger the telegraph and telephone interests.

606. In case of storms, washouts, accidents or other occurrences causing prostration of the pole lines or otherwise affecting the circuits, they must obtain full information of the extent of the damage, communicate promptly with the proper officer, assemble men and material where necessary and proceed to the point of interruption with the greatest possible haste to make the required repairs.

607. They must investigate failure or improper working of the plant and take action that will insure repairs being made promptly.

608. They must not make, or permit to be made, any alterations or additions to the plant without proper authority.

ASSISTANT GENERAL FOREMEN, DISTRICT FOREMEN, SUPERVISORS OF LINES AND INSPECTORS OF OUTSIDE PLANT

620. Assistant General Foremen, District Foremen, Supervisors of Lines and Inspectors of Outside Plant report to the General Foreman of Telegraph and Telephone. They shall be in charge of such forces and perform such duties as may be assigned to them by the General Foreman of Telegraph and Telephone.

FOREMEN LINE GANGS

625. Foremen of Line Gangs report to and receive instructions from the Assistant General Foreman, District Foremen, or Supervisors of Lines, as may be designated by the General Foreman.

626. They will have charge of such forces as may be assigned to them. They must see that employees properly perform their assigned duties. They must keep the prescribed records of the time of employees, and of the receipt, distribution and use of material supplied.

627. They will have charge of and be responsible for such tools and material as are necessary for the performance of their work and must know that they are properly used.

628. They must obtain advance authority from their superior officer for any work involving the removal of any part of the plant that would interrupt the service.

TELEGRAPH AND TELEPHONE MAINTAINERS—SECTION LINEMEN

635. Telegraph and Telephone Maintainers—Section Linemen, report to and receive their instructions from the Assistant General Foreman, District Foreman or Supervisors of Lines, as may be designated by the General

Foreman. They shall also obey instructions issued by the Wire Chief in regard to clearing trouble and must keep him advised of the work they are engaged upon and of their whereabouts at all times.

636. They are responsible for the safe condition and proper maintenance of pole lines, wires and the equipment as may be assigned to them and for the economical use of material supplied them.

637. They must not permit any foreign wires or fixtures to be attached to telegraph or telephone poles, without the approval of their superior officer.

638. They must report to their superior officer anything contemplated or existing that may interfere with telegraph or telephone service or in any manner endanger persons or property; for example: new work of any character; track changes; power transmission lines within 500 feet of the railway right-of-way; other paralleling lines, the poles of which would be within striking distance of the railway right-of-way; new wire crossings; unsafe conditions in existing wire crossings; attachments of wires to buildings and other structures, etc.

639. They must keep an accurate pole diagram of the wires in their district, and when changes affecting such diagrams are made they shall advise the proper officer in order that the records may be kept complete and up-to-date.

640. They must make inventory and work reports upon prescribed forms and forward promptly to the proper officer.

641. They must notify their superior officer before taking out of service any part of the wires or apparatus, and authority must be obtained, except in emergency, before such wires or apparatus are taken out of service. Should an emergency arise which requires the removal from service of any part of the wires or apparatus, the proper officer must be notified by wire immediately.

642. In case of accident or serious damage to wires or apparatus in their district, they must immediately proceed to the point of interruption, requesting such assistance and material as may be required, and make every effort to restore the circuits promptly in the order of their importance.

643. They must make such inspection, tests and repairs of plant in their district and supply such reports as are required.

CONDUCT OF WORK

CARE OF RIGHT-OF-WAY

650. Section Foremen must keep their sections in a neat and orderly condition, and shall devote sufficient time to cleaning and putting things in order around section toolhouses, station grounds, yards, sidings, highway and farm crossings, and the right-of-way generally.

651. Borrow pits or low spots must be drained or filled.

Fencing

655. Section Foremen are responsible for the proper inspection of fences on their respective sections. They must report to the Supervisor any destruction of fences by flood, fire, or otherwise, making such temporary repairs as possible, and endeavoring to keep stock from getting upon the right-of-way or tracks, until permanent repairs can be made. They must endeavor to keep all gates closed, securing so far as possible the co-operation of the adjacent landowners in this effort.

Mowing

660. Section Foremen, under the direction of the Supervisor, are responsible for compliance with all the laws, rules and regulations in effect in their respective districts, with reference to mowing and fire protection.

661. Rough ground (or surplus ditching material) must be smoothed to permit use of mower.

Cleaning

665. Section Foremen must for reasons of economy as well as neatness, collect scrap and usable material from the right-of-way, disposing of the same as directed by the Supervisor. They must see that no trees which by their location or condition might endanger trains or the telephone or telegraph wires, are left standing on the right-of-way or adjacent thereto, obtaining permission to cut trees not on the right-of-way, if possible to do so. They must endeavor to keep the tracks and right-of-way in a neat and tidy condition.

ROADBED

Drainage

General

670. Thorough drainage of the roadbed is absolutely necessary before good track can be secured or maintained, and this matter must be given careful detailed consideration at all points.

Surface Drainage

675. Ditches must be kept open at all times so as to divert the water from the roadbed quickly. Ditches must be dug out thoroughly and restored to full size in the spring and late fall. Side ditches must be dug uniformly and parallel with the track, and conform to the standard roadbed sections.

676. Intercepting ditches must be constructed along the top of the bank for the protection of cuts, where the drainage area would be likely to collect sufficient water during heavy rains, from the higher ground adjacent, to wash the slopes.

677. The end of a ditch must be diverted from the track, so that the scouring action of the water will not weaken or wash away the roadbed.

678. Waterways leading to and from bridges and culverts must be kept clean within the limits of railroad property. Culverts must be kept open for the free and unobstructed passage of water at all times.

679. In regions of heavy snows, ditches must be cut through the snow, wherever a sudden thaw would be likely to flood the track, and all ditches must be cleaned when the snow is melting in the spring.

680. Cross-drains must be put in at proper intervals, where directed by the ....

Underground Drainage

685. In wet or narrow cuts, where side ditches cannot be effectively maintained, sub-drains must be provided, as directed by the .... who will determine the size and character of drains to be used. Such drains must be laid to a true grade and in conformity with standard plans.

CARE OF ROADWAY

General

690. The cross-section of the roadway must conform to the standard plans. No deviation from the sections shown shall be made without proper authority.

691. Growth of vegetation on the slopes of cuts and embankments shall be encouraged to prevent erosion.

692. Material taken from cuts or from right-of-way along embankment for general widening or for other purposes, must be so handled that both the place from which it is taken and the place where used will be finished in a workmanlike manner and leave the surface smooth and of good appearance.

Ties

Storage

695. Ties stored along the right-of-way must be stacked to conform to the standard plans, according to class, shape and location. Stacks must be placed on ground bare of debris or vegetation for at least two feet around each stack and clear of vegetation over six inches high within ten feet of any stack and sufficiently well drained so that water will not stand under the stacks or in the immediate vicinity. Decayed ties or wood must not be used for sills. Decaying wood debris must be entirely removed.

Inspection for Renewals

700. The ties in track must be inspected at stated times each year and those which will not last until the next inspection marked for renewal. This inspection shall be made preferably by the Supervisor personally, accompanied by the Section Foreman. The Supervisor must report to the Division Engineer on the proper form, the number of ties marked for renewal on each mile and each section. This report shall be carefully checked by the Division Engineer and where any unusual or unfavorable condition is indicated, a thorough investigation shall be made to insure proper renewals.

Methods of Renewals

705. The renewal of ties shall be started when directed by the Division Engineer. All defective ties removed from track each day must be placed for burning or loading on cars. The Supervisor must frequently inspect ties removed from track to see if any have been removed which might have remained in the track with safety until the next inspection.

706. Ties must be spaced according to the standard plan. All ties shall be placed square to the line of rails. The outside ends on double tracks, and the ends on one side throughout on single track, must be lined parallel with the rail.

707. Ties must be laid so as to obtain the best bearing. Untreated ties must be placed in track with the wide surface having the most heartwood down; treated ties must be placed in track with wide surface nearest the pith down, or if the pith is not present in the tie, with the widest surface down. Ties shall be adzed only when necessary to obtain a full bearing under rail or plate.

708. Ties must be moved with tongs so as to reduce the damage incident to handling; picks, mauls, sledges and spiking hammers must not be used in moving ties or placing them in position beneath the rail.

Anti-Splitting Device, Tie Plugs and Dating Nails

709. Any tie which starts to split in track should have an anti-splitting device applied promptly.

Use of Tie Plugs

710. Whenver spikes are drawn from ties, creosoted tie plugs must be driven into all holes, except in ties which are to be renewed that season. In replacing spikes, they must be driven into the plugs.

Dating Nails

711. When dating nails are applied after the ties are in the track they must be driven the same day the ties are inserted.

712. The Section Foreman must see that marks or nails intended to identify ties are not injured or destroyed.

Records

715. Accurate records of tie renewals and all data of value in connection therewith must be kept on prescribed forms.

RAIL

Distribution and Handling

720. The most expensive and the most easily damaged part of the track structure is the rail, therefore care must be exercised in unloading and handling. In unloading from cars, rail must be skidded or otherwise carefully lowered to prevent injury. Where it is necessary to drop it, both ends must be dropped at the same time, and the greatest care taken to avoid its falling on hard or uneven surfaces. Rail received in gondola cars should be unloaded with an approved device to prevent injury.

721. Rail must be distributed, as far as practicable, where it can be laid with the least amount of handling. Unless rail is to be laid at once, it must not be distributed through yards and station grounds where trainmen and others are liable to stumble over it.

Renewals

722. Rail laying may be done in the winter months, or at such seasons of the year, depending on the climate, unfavorable for doing other track work.

723. Where practicable, rail must be laid one at a time. Standard expansion shims must be used.

724. Care must be exercised by those in charge of rail laying gangs to see that adzing is carefully done and rail left in proper line, gage and surface. Shims must be used if the track is frozen and ties cannot be lifted to eliminate low spots. Tie plates and anti-creepers must be placed the same day rail is laid. It is especially important to prevent creeping of rail by applying a sufficient number of anti-creepers at once, as rail creeping changes the expansion in the joints, making some joints wide and others close, resulting in battered joints, and in hot weather danger from buckling of the track where joints are tight.

725. Rail shall not be curved before laying except for curves above .... degrees.

726. Kinked or crooked rail must be straightened before being laid; if surface bent, it must either be straightened or removed.

727. In making temporary connections in main tracks, an old rail must be cut and fastened to the new rail, using compromise joints when necessary.

728. When replacing rail of approximately the same width of base, so that the tie plates need not be changed, but two lines of spikes are to be drawn. When a different tie plate is required, all spikes must be drawn. Where no tie plate is required, all spikes must be drawn. Where no tie plates are in use but three lines of spikes need be drawn for any change in the width of base of rail.

729. Spikes shall be driven vertically with face in contact with the base of rail. They must not be straightened while being driven. Rail must be full spiked, and the spikes staggered so that outside spikes will be on the same side of tie, and inside spikes on opposite side. Where shoulder tie plates are used, a third spike may be driven on inside of rail, with back of spike against base of rail. Good second-hand spikes must be used for the third spike.

730. Joint bars must be securely fastened with the full number of bolts. At permanent connections of rail of different sections, compromise joints must be used.

731. For the preservation of the rail, and to secure the proper bearing for carrying the loads, and distributing the weight of the rolling stock uniformly over the rail and to the roadbed, the ties must be spaced uniformly.

Bonding

735. Where track circuits are used for operation of signals or other purposes, bonding of rail is necessary. This feature must receive proper consideration and the work be carefully and efficiently performed. Where air, electricity or other power is available, any mechanical arrangement which will operate drilling machines successfully is preferable.

Replacement—Inspection of Rail in Track

740. Accurate records of rail renewals and all data of value in connection therewith must be kept on prescribed forms. These records must

be kept up to date, every change, whether of individual rails or many rails, being recorded immediately.

741. Track walkers must be properly instructed to look for broken or defective rails, and report same, when discovered, to the Section Foreman, taking proper precaution to protect traffic, if necessary, on account of the condition of the rail found.

742. Where rail failures become numerous, especially if transverse fissures develop, a special rail inspection may be arranged. This can be facilitated by the use of a mirror attached to a short wire handle for examining the inside and underside of the head of the rail. A good magnifying glass with which minute defects or hair line cracks can be inspected, is desirable.

Broken Rails

745. A broken rail found in the main track must be protected immediately by a flagman and no trains allowed to pass over it until it is determined that the rail is in such condition as will permit the safe passage of trains. If it is decided trains may pass over the rail safely, all trains must be stopped before reaching the break, and then allowed to proceed at slow speed. If a suitable rail is available, the broken rail must be replaced immediately; otherwise, if practicable, the broken ends of the rail must be connected by joint bars, the rail drilled and the joint bars full bolted, after which the resumption of traffic may be permitted with reduced speed. The rail must, however, be removed from the track as quickly as possible.

OTHER TRACK MATERIAL (EXCLUSIVE OF FROGS AND SWITCHES)

Joint Bars

750. Joints must be kept well oiled, both as a preservative from rust and to facilitate expansion and contraction of the rail.

751. Insulated joints must be installed only on rails conforming to the section for which they are designed. Care must be taken, when installing such joints, to properly place the insulation, and not to damage the fiber or bushings. Ties under and adjacent to insulated joints must be kept well tamped.

752. Before applying an insulated joint, all scale, dirt and other foreign matter must be removed from the rail end and joint parts. Clean, smooth bearing surfaces are necessary to obtain good fit and durability. All burrs, lips and rough edges, which might cut into the insulation, must be removed from the rail ends, by cutting or filing them off before the joint is applied.

Track Bolts

755. As large track bolts must be used as the holes in rail and joint bars will permit.

756. Track bolts must be kept tight and well oiled.

757. Track bolts must be gone over and re-tightened after new rail has been laid, as soon as traffic has worn the mill scale and rust off the joint bars and settled the bars into place.

758. Proper wrenches for tightening track bolts shall be furnished and must be used without modification. Care must be exercised in tightening bolts to avoid twisting the bolt or stripping the thread.

Track Spikes

764. Spikes must be started and driven vertically and square, and so driven that the face of the spike shall come in contact with the base of the rail; but not driven so far as to cause the neck to bend and/or the head to crack or break off.

765. Where track is to be spiked to standard gage, the rail must be held against the gage with a bar while the spike is being driven.

766. Badly bent, crooked, or neck-cut spikes must not be used, especially in main track. Good spikes, which are bent, must be straightened before being used.

Anti-Creepers

770. Anti-creepers must be applied where directed by the .... The number of anti-creepers per rail will depend upon the physical characteristics of the track and amount and character of traffic.

771. In the application of anti-creepers care must be exercised to use proper tools, properly apply the anti-creepers, and not damage any of the parts. The use of spikemauls or heavy hammers is prohibited.

Tie Plates

775. Tie plates must be used where directed by the ....

776. When applying tie plates care must be exercised to see that the plates have a full, even bearing on the ties, that the track is in correct gage before they are spiked to the tie, and that the shoulder of the plate rests against the base of rail for the full width of the plate. The shoulder of the plate must not be under the base of rail.

BALLAST

General

780. The kind and amount of ballast to be applied should be determined by the proper official.

781. The Division Engineer should lay his plans for work train service before the Division Superintendent in order that there may be a clear understanding of what is desired to be done.

782. Speed restrictions must be arranged for in accordance with operating rules before track is disturbed and must be maintained until track is in safe condition for schedule speed.

783. Section Foremen must provide proper protection by slow order, caution signs, or flag, or all of these, if necessary, when raising track, and must, except in emergency, raise against the current of traffic, where there is more than one track. A long easy runoff must always be prepared ahead of fast passenger trains.

784. A careful inspection of pit tracks and appurtenances must be made and everything put in serviceable condition if the ballast is to be secured from a Railway Company pit or from one for which the Company is responsible.

Preparatory

785. Preparatory to placing ballast, the roadbed must be widened, if necessary, to bring it to the A.R.E.A. standard width, by dumping material alongside of the track and spreading it to the required width and slope, by the use of a material spreader, if available. Where necessary to raise the roadbed level, porous material must be used to avoid the forming of water pockets.

786. All bank widening must be done far enough in advance of the ballasting work so that there will be no interference with progress of the work.

787. Where directed by the Division Engineer, preparatory to the distribution of new ballast, all old ballast and unsuitable material must be removed to the bottom of the ties, for the full width of the roadbed, the old ballast cleaned, and the unsuitable material used for widening embankments or for other purposes. At the same time, all ties requiring renewal must be replaced and the ties properly spaced, if necessary. The track must be accurately gaged as the new ties are being spiked up. Old ties must be disposed of as directed.

788. Ballast grade stakes must be set after the ditching, bank widening, skeletoning and re-tieing have been done and before the ballast material has been dumped and spread. It is desirable to avoid, as far as possible, interference with the stakes, yet to have them available as a guide for the unloading of ballast.

789. All drains required to take care of water from between tracks must be placed before the ballast is unloaded.

790. Stone and hard slag ballast must be cleaned when so foul as to prevent proper drainage. Cleaning should be to the sub-shoulder and where cribs are cleaned, to the bottom of ties, but if the cribs are not cleaned, cross ditches should be cleaned at least every rail length but no cross ditch should be placed at any rail joint. Cleaning between tracks should be to a depth of six inches or more below the bottom of the ties.

Unloading

791. When old ballast has been thoroughly cleaned, sufficient new ballast should be unloaded to make the first raise, which is usually made by shovel tamping the ties. When ballasting or surfacing track out of face, both rails must be raised together.

792. Cars for transporting ballast must be carefully chosen with regard to the work to be done. If for raising track, center dump cars should be used and ballast spread with plow or tie drag. When unloading ballast for a parallel track, side dumps are preferred, especially when air operated. Convertible cars where the sides swing out and up, when used with side plow and unloading engine drum and cable, are satisfactory when dump cars are not available.

793. Ballast shall be unloaded by dumping or plowing as the cars provided permit. If the ballast be in center dump cars, it must be unloaded by having one or more cars opened a little at a time and allowing the desired amount of ballast to flow out as the train is slowly moved along. If the ballast be on flat or open side cars, it shall be plowed off by means of

an unloading machine while the train is standing or moving at such a rate of speed as to provide the desired amount of ballast.

794. The unloaded ballast must be leveled down by means of a plow or a spreader, consisting of a heavy timber placed in front of the leading pair of wheels of the rear truck and so constructed and used as to avoid sliding of the car wheels on the rail.

795. When unloading ballast, care must be exercised to secure proper distribution and avoid waste.

Ballasting

796. In using jacks, they must be placed outside the rail and close enough together to prevent undue bending of the rail or overstrain of the joints. When the roadbed material is heavy or holds to the ties tenaciously, it is sometimes necessary to place three or more jacks per rail length. Jacks should be worked in pairs directly opposite each other, and a sufficient number should be used simultaneously, so that no jack will raise the rail more than four inches above its level at the next succeeding jack or place of support.

797. In gravel, stone, chats, chert, slag, hard burnt clay and cinders, the ties must be tamped from fifteen inches inside the rail out to the ends. The end of the tie outside of the rail must be tamped first, and if possible, a train allowed to pass over before tamping on the inside of the rail. The space under the rail must be tamped well. The center of the tie must not be tamped.

798. In earth or clay ballast the ties must be tamped from eighteen inches inside the rails out to the ends. The end of the tie outside of the rail must be tamped first, and if possible, a train allowed to pass over before tamping the inside of the rail. The space under the rail must be tamped well. The center of the tie must be tamped loosely with the blade of the shovel. The dirt or clay between the ties must be placed in layers and firmly packed with the feet or otherwise so that water will quickly shed. The earth must not be banked above the bottom of the ends of the ties, the filling between the ties must not touch the rail, and in the middle of the track should be as high, or higher, than the top of the rail.

799. Where track is electrically bonded, the ballast must be kept at least one inch below base of rail. At road crossings, platforms, etc., where this is not practicable, rails may be insulated by painting them with an asphaltum or tar product, and good, clean stone mixed with the same material may be used for at least one foot each side of rails.

800. Where raise is sufficient to require a filling lift, a preliminary surfacing gang must follow the unloading as closely as the regularity of the ballast supply will permit.

801. The amount which the track should be raised at one lift will depend upon the depth of ballast to be applied. Usually, track should not be raised more than six inches at a lift. Both rails must be raised at one time and as nearly uniformly as practicable.

802. The "filling lift" must be made by jacking the track up to the required height and the ballast then forked or shoveled in and worked to as uniform a surface as possible by the use of shovels. It shall then be left to be compacted by traffic, but a small "lookout" gang must go over it after a

few trains have passed and pick up any spots that show too great an inequality of settlement.

803. After a few days, depending upon the amount of traffic over the track, another lift shall be made, either another filling lift or a finishing lift, according to the depth to which the track is to be ballasted. If another filling lift, it must be made in the same manner as the first one.

804. When the track has been raised to within two or three inches of the final grade and properly compacted, a finishing lift must be made by jacking up the track to the desired grade and the necessary ballast forked or shoveled in and then driven to place by the tamping machines, tamping picks or bars, if rock or heavy ballast is used. Shovel tamping should be used with gumbo, cinder or light sandy gravel ballast. In making all lifts, the spot board and level board must be used with care, and the track brought to surface.

805. Center stakes must be set for the alinement before the finishing lift is made, and the final alinement must conform to the center stakes.

806. The track must be placed in good alinement before the finishing lift is made, but a lining and surfacing gang shall follow one or two days' work behind the finishing lift to pick up all low spots and give the track the final alinement.

807. After the track has been given final line and surface, the track center shall be filled in to the required depth and ballast dressed out to the proper shoulder or toe, using a template if necessary to secure the standard section.

808. Boulders, clinkers or any refuse from the ballast must be removed and disposed of so as to not disfigure the right-of-way and interfere with the mowing.

809. The following tools should be used: For stone or slag ballast—shovel, tamping pick, tamping machine and/or stone fork; for gravel, chats, chert, hard burnt clay, or cinder ballast—shovel, tamping pick or tamping bar; for earth or clay ballast—shovel or tamping bar.

LINING AND SURFACING

811. As early in the spring as the weather and track conditions will permit, the entire section must be gone over and smoothed up. At this time special attention must be given to those portions of the section on which no tie renewals or ballasting is expected to be done during the season, and this track put in 100 per cent condition. Where tie renewals are to be made or ballasting is to be done, no unnecessary work shall be done, the aim being to keep these portions of the section sufficiently smooth for safe and comfortable riding, until the work of renewing ties or ballasting can be accomplished.

812. Where the track shows evidence of being badly out of line on curves, and there is opportunity to do so, line stakes shall be set by Engineers. (Section Foremen, assisted, if necessary, by the Supervisor, can line the track very accurately and secure practically perfect riding curves by the use of a string sixty-two feet long, holding the ends against the gage side of the high rail and measuring the distance from the middle

of the string to the gage of rail, each inch of distance representing one degree of curve.)

814. When raising or surfacing track, Foremen must not trust to their eyesight alone, but must use the track level boards and sighting boards. Track level boards must be tested frequently.

815. When not surfacing out of face, as in case of picking up low joints or other low places, the general level of the track must not be disturbed.

Shimming

820. Wooden shims placed under the rails must be used to maintain the proper surface of the track, when the surface is disturbed by the action of frost, or when other conditions make tamping impracticable.

821. When shimming, the track level and track gage must always be used.

822. Shimming must be done on top of the tie. No shimming shall be done under the tie, except in emergency and shims so placed must be removed as soon as possible.

823. Shims must be the same thickness throughout, and not wedge shaped; they must have an even bearing on the tie.

824. Where shims are used the rails must be securely braced to prevent spreading. (Tie plates with one end placed against the outside under the head of the rail, and the other end spiked to the tie may be used when other braces are not available.)

825. Section Foremen must watch track which has been shimmed, testing frequently with the gage and level board to make sure that shims are in place and tight and that track does not get out of gage or surface.

826. When the frost is leaving the track, shims must be changed frequently, replacing thick shims with thinner, until the necessity for shims has passed. As soon as the frost is entirely out of the track, all shims must be removed and the track surfaced, if necessary. Care must be exercised, however, that track surfacing is not done before the frost has all gone.

Gaging

830. Uniform gage is essential to good track and must be maintained.

831. The standard gage is 4 ft. 8½ in. Curves of eight degrees and under shall be standard gage. Gage shall be widened ⅛ in. for each two degrees or fraction thereof over eight degrees, to a maximum of 4 ft. 9¼ in. for tracks of standard gage. Gage, including widening due to wear, must never exceed 4 ft. 9½ in.

832. Where frogs occur on the inside of curves, the gage at the frog must be standard, unless a frog with widened flangeway is used, in which case gage must be widened to correspond with widened flangeway.

833. If the track is allowed to remain out of line or out of surface for any length of time, bad gage is likely to result therefrom, therefore Section Foremen must always check the gage and make any necessary corrections when lining and surfacing the track out of face.

834. Track gages must be checked frequently with a standard gage to assure that all gages are correct. This shall be done each year in the winter months, and the gages painted a new standard color each time tested.

Elevation of Curves and Easements at Ends of Same

840. The elevation on curves and the easements at the ends of same must be in accordance with requirements and according to prescribed standards.

841. Where the maximum speed allowed by timetable is higher than the maximum standard elevation will safely permit, the speed must be reduced accordingly. Signs shall be placed at the beginning of each curve where the speed must be reduced below the maximum allowed by the timetable. The signs shall show in plain figures the maximum permissible speed.

842. Speed is the principal factor in elevation on curves, and the degree is a secondary factor only. Section Foremen must not vary from the prescribed elevation without proper authority. Where there is considerable freight traffic and passenger traffic is not so important, it is preferable to keep the elevation low on the curves, and slow down the passenger trains to meet the conditions.

843. Where possible, posts must be placed at the side of the track for the guidance of Section Foremen. These posts, indicating the elevation in inches and fractions thereof, shall be set at the beginning of the easement; at the beginning and end of the regular curve, and at the end of the easement or point of the tangent. Posts must also be set at the points of compound and at each end of easements, between compound curves.

FROGS AND SWITCHES

851. Track must be kept in good line and surface through frogs and switches, and Section Foremen must give these features special attention.

852. Switches and frogs must be inspected as directed by the .... to see that they are in proper working order, and that all nuts, bolts and other fastenings are in place and properly tightened. Any broken or damaged parts must be replaced promptly.

853. Switch points must fit closely and accurately to the stock rail, which must be bent in accordance with the prescribed standards. When renewing a switch point, the stock rail must also be renewed, if necessary, to secure a proper fit of the point. In like manner a new stock rail should not be used with a worn point, in order to prevent danger of derailment if the stock rail is higher than the switch point.

854. Frogs must be protected by guard rails, constructed and placed in accordance with standard plans. The tops of the guard rails must be level with the main running rails, and must be securely held in place.

855. Guard rails must be so placed that the gage distance from the frog point to the flangeway side of the guard rail will be at least 4 ft. 6¾ in., and the distance between the flangeway sides of the wing rail and guard rail shall not exceed 4 ft. 5 in.

For the widening of gage and flangeways on curves for the operation of specific locomotives or for special conditions and for curved crossings, refer to Tables No. 1 and No. 2 for "Gages and Flangeways in Curved Tracks."

856. Switch rod and connecting rod bolts must be equipped with cotter pins. Bolts must be inserted with the nut on top for convenient inspection.

857. Switches must be kept free from obstructions at all times and free from ice and snow in winter. The slide plates must be kept well oiled.

858. Switch stands must be kept firmly spiked to the head-block ties, must be set plumb, and with the target square with the track.

859. Automatic switch stands must be inspected frequently for lost motion. They must be kept well oiled. Head-block ties must be kept firmly tamped.

860. Switch stands must be placed, wherever possible, on the side of the track where the connecting rod will be in tension when the switch is set for the main track. The switch banners and lamps must be placed on the right hand or engineer's side of the track approaching facing point switches.

861. Switch stands and facing point switches on multiple tracks and main track switches on single track must be equipped with switch lamps of approved design, which will show the "proceed" color when switch is set for the main track, and the "stop" color when switch is open.

862. Unless otherwise provided for, Section Foremen will be responsible for the proper care and maintenance of switch stands and lamps and must give these devices careful attention. Switch stands must be kept tight on the head-blocks and adjusted to give the switch the proper throw and to keep the points tightly against the rails, when the switch is closed, either for the main track or the turnout.

863. Switch lamps must be kept clean, supplied with oil, properly adjusted, and firmly placed on the switch stand, so they will not jar out when the switch is used.

864. Main track switches, not interlocked, must be kept locked at all times except when in actual use by trains, or when being inspected. Section Foremen must report immediately main track switches found unlocked or with the lock missing.

SWITCH TIES

870. Switch ties must be used for all permanent turnouts, crossovers and railroad crossings, and must conform to the standard specifications. They must be placed in track in accordance with the standard plans.

871. For temporary work, track ties may be used, lapping them in place of switch ties, but switch ties must be used for head-blocks and for at least three or four ties under the frog and guard rails.

TRACK SIGNS AND POSTS

875. Track signs and posts must be placed and maintained in accordance with standard plans and special instructions.

876. Section Foremen must see that all track signs and posts are in their proper places and kept plumb, and that weeds and other vegetation are not permitted to obscure the view of same.

ROAD CROSSINGS

880. Section Foremen will be responsible for the proper care and maintenance of public and private road crossings.

881. Road crossings shall be constructed and maintained according to standard plans, and must conform to legal requirements.

882. Road crossing signs, where required by law, must be maintained. Such signs must be properly placed and kept clear of obstructions which would interfere with the view of travelers on the highway. Where possible, the permission of adjacent landowners should be secured, if necessary, and all brush or trees, obscuring the view of approaching trains, removed.

883. Holes or pockets in bituminous crossings must be repaired as soon as they appear and a small quantity of material should be kept on hand for this purpose.

TRACK TOOLS

891. All track tools are furnished by and remain the property of the Company.

892. Section and other Foremen in charge of men will be held responsible for the proper care and use of tools. They must know that they have at all times a sufficient supply, in serviceable condition. They must see that tools are not lost or broken, and when not in use, are not left where they are liable to be struck by trains or derail trains.

893. When not in use, all tools must be collected and properly protected from the weather and from being stolen. Where it is not practicable for Foremen to take all tools to the toolhouse each evening, suitable tool boxes, equipped with substantial locks, shall be provided, and all tools must be placed therein each night.

894. Labor-saving devices and appliances must be used wherever such use is economical.

895. Rail-handling and rail-laying machines or locomotive cranes shall be used in laying rail, where available.

SIGNALS AND INTERLOCKING

(Reference is also made to Manual of Signal Section, American Railway Association, for additional rules.)

Track Circuits

900. The track must be kept clean and ballast kept clear of rails.

901. The track must be kept well drained, especially at road crossings and station platforms.

902. In case of rainstorm, weak track circuits must be tested and adjusted.

903. When track circuits are fed from storage or caustic soda batteries, proper resistance must be maintained between the battery and the rail.

904. Cases where excessive amount of sand is used, or ash pans are cleaned on trunking or bootleg connections, must be reported.

905. Insulation in joints, switch rods and switch instruments must not be allowed to wear to deterioration.

Relays and Indicators

910. Meters for testing relays and indicators shall be calibrated as often as necessary for field use.

911. Tests shall be made as required and reports made on prescribed form.

INSULATED WIRES AND CABLES

915. Ducts of all kinds must be properly inspected before being installed. Look for blisters and sharp teats on the vitrified clay duct and for fins, scale and rusted through spots in metal conduit.

INTERLOCKING PLANTS

920. Time locks must be kept properly adjusted.

921. Circuit controllers must be kept properly adjusted.

922. Electric locks must be kept in good working order, contacts properly adjusted, and must be kept sealed or locked.

BUILDINGS

General

950. Station platforms should be kept clean, free from rubbish, snow and ice, and defects immediately repaired.

951. Apparatus for extinguishing fires must be kept in place and at a location easily accessible from in or outside of building, in good working order at all times and properly protected from freezing.

952. Small defects, such as broken glass, locks, wood work, etc., must receive prompt attention. Toilet facilities, water and sewer leads must be maintained in good order. Attention must be given to supplying durable hardware for all buildings.

953. Heating appliances must be inspected in the spring or early summer, so as to allow ample time to obtain repair parts and make necessary repairs, and all parts must be thoroughly tested after being repaired.

954. Ice houses must be placed in condition in time to receive the season's supply. Doors, runways, ventilators, etc., must be kept in good condition at all times.

955. Before relocating or altering buildings or platforms of minor importance, not requiring plans or specifications, careful consideration must be given to possible changes in alinement and grade of tracks and public improvements.

956. During the reconstruction or alterations of buildings, special consideration must be given to the safety of the public.

957. Leaky faucets and valves must receive prompt attention, as they may damage other work and increase water expense.

Construction and Maintenance

961. Whenever practicable, buildings must be located on outside of curves and far enough from road crossings to avoid obstructing the view of trainmen or of travelers on the highway.

962. Local laws and permits required by municipalities must be complied with and all necessary permits must be obtained.

963. Alterations or additions not covered by plans must conform as nearly as possible in appearance to the main building to which they are attached.

964. Proper authority must be obtained before the construction of any building.

965. Work in progress must always be kept safe for trains, the public and for employees. Each piece of work must be completed before going to another, except in case of emergency.

966. High platforms and buildings on timber foundations must be enclosed to prevent accumulation of paper, rubbish, scrap, etc.

968. Cornices, gutters, downspouts, and other places of lodgment must be kept free of obstructions.

969. Maintenance of all portions of buildings and structures not easily accessible, such as roof trusses, rods, cornices, under supports, gutters, downspouts, inside posts and braces, must be given special attention.

970. Report must be promptly submitted to proper official covering buildings on property leased from the Railroad and owned by outside parties, that are not properly maintained or painted.

971. In order that the insurance schedule may be kept up-to-date all changes, either in renewals or repairs, which may in any way affect the value of the 'building or structure, must be reported through the proper channels.

972. If a building or other structure is burned or damaged, an inspection and report must be made as soon as possible, giving the nature and extent of the damage, with an estimate of the cost of repairs.

973. Foremen in charge of work must supervise the construction of scaffolding to see that it is safe.

974. The date of erecting and painting of all buildings must be plainly indicated on the structure in an inconspicuous place and preferably where sheltered from the weather.

975. In constructing and maintaining buildings and platforms, careful consideration must be given to proper drainage, to permanent alinement and grade of tracks, to public improvements and to future changes.

976. Buildings and other structures must be constructed and maintained with standard clearances. Special authority must be obtained to vary therefrom.

977. Main line passenger and freight platforms built new, must be located with reference to track and in accordance with standard plans, and old platforms changed or renewed must be brought to standard where practicable.

978. Runways or ladders must not be located under scaffolds, or at other points where tools or material are likely to fall, and where a considerable amount of work is in progress barricades must be erected.

979. Rope and tackle scaffolds which have been stored or shipped must be thoroughly tested for deterioration or injury before being used.

980. Bulletin boards must be provided in or around completed structures for the posting of notices.

981. Station signs must be placed in conformity with the prescribed standards and maintained in good condition.

Painting

1000. Careful supervision must be given to all painting, and special care exercised to obtain proper cleaning and application of first coat of paint.

1001. Before paint is applied, the surface must be cleaned of all grease, dirt, oil, rosin, scales, blisters and paint which does not adhere firmly.

1002. The first coat of paint must be applied as soon as possible after cleaning. Large structures must be cleaned and painted in sections.

1003. Painting must be done only when the surface of the material is perfectly dry. It must not be done in wet or freezing weather, unless protected.

1004. Paint must be thoroughly mixed before it is removed from the container. If the paint contains lumps or paint skins, it must be strained and thoroughly stirred before applying.

1005. Each coat of paint must be well brushed out to provide a uniform gloss and color and coats should be of sufficient thickness to properly protect the material.

1006. Each coat of paint must be allowed to thoroughly dry before applying another coat, and each coat must entirely cover previous coats.

1007. Where special paint or other protective coating is desirable, the proper officer must be notified and authority requested for its use.

1008. When painting steel structures, the date, kind of paint and number of coats applied must be stenciled in plain characters on one or more members where the characters can be easily found.

1009. Machine finished surfaces of old steel stored for re-erection (except abutting joints and base plates which are painted) must be coated with white lead and tallow applied hot.

1010. At least once each year all exposed structural steel surfaces showing sign of scaling paint or rust must be cleaned and painted.

1011. Steel structures exposed to brine, engine gases, etc., must be frequently and carefully examined, and, when necessary, cleaned and painted to protect the steel from corrosion.

1012. Unpainted surfaces of old steel structures which are not to be scrapped immediately must be painted when the structure is dismantled.

1013. When painting buildings, the date must be stenciled in plain characters on one or more places on the building where the characters can be easily found.

1014. Necessary repairs to buildings must be made before painting. Repaired parts of painted woodwork must be primed as soon as practicable after repairs are made and before a full surface coat of paint is applied to the entire structure.

1015. New woodwork must have all knots and sap streaks covered with thin shellac before priming. After priming all nail holes, cracks and indentations must be neatly filled with putty and painted with one or more coats of color.

1016. Private buildings erected on the right-of-way must be painted by their owners with a prescribed standard color.

1017. When painting the interior of station buildings and telegraph offices, care must be used not to paint insulated wires and cables, because of the deteriorating effect of ordinary paint on insulation.

WATER SERVICE

Boilers and Steam Pumps

1025. Fire must be frequently cleared of clinkers, and ashes and soot removed from flues. Ashes must not be allowed to accumulate beneath the grate.

1026. Too much coal must not be put on the fire as this will result in incomplete combustion, black smoke and poor steaming effect. Too thin a fire must not be carried as this will result in an uneven fire with too much air supply and poor steaming effect.

1027. To bank fire for the night, clean the fire carefully, removing all clinkers and bank fire well with wet slack coal.

1028. Boilers must be washed at least every 30 days or as often as local water conditions make it necessary. Foaming is due to concentration of soluble salts and suspended matter and can be stopped by filling boiler with water and blowing down. To blow down boiler, first fill to top gage cock and blow down to one gage. Repeat as often as water conditions make it necessary.

1029. If it develops, when plant is operating, that no water appears in the water glass the valve below water column should be opened. If water then appears, the flow to the boiler can be increased; if not, fire must be pulled and boiler cooled before turning any water into it. Where more than one shift is in charge of the pumping plant, each oncoming man should be notified by the man leaving of any defects.

1030. Should safety valve stick and steam gage show over-pressure, draft doors must be closed and boiler allowed to cool off to pressure at which valve is supposed to work before any repairs or adjustments of the safety valve are attempted.

1031. In starting a steam pump, first open all cylinder cocks on steam cylinder to let out condensed steam and fill the lubricator; then open throttle valve a trifle to warm up cylinder and give the condensed steam time to run out of cylinder.

Oil Engines

1032. Attendant must be provided with a copy of and be governed by the manufacturer's printed instructions for operating the particular type of engine in his charge.

1033. To secure economical and satisfactory operation, engines must be properly lubricated. Attendant must see that all moving parts are free from dirt, properly oiled and work easily. Lubricating oil must be fluid enough to be fed readily through the oiler. When oiler is being filled the lubricating oil must be run through a fine mesh strainer inserted in a funnel. The cover of the oiler must be in place at all times, except when filling. The oiler must be drained occasionally and washed out with gasoline. This applies also to the bearing oil cups.

1034. The machinery to be driven must be detached from the engine until engine is in motion.

1035. Before starting see that tank contains fuel and that a supply of cooling water is available. Thermometers are frequently provided which show the temperature of the cooling water around the cylinder. When running the thermometer should register 140 to 180 degrees Fahr. The most favorable temperature will be different with different fuels, and attendant must note the temperature at which operation is best and attempt to keep it reasonably close to that figure. The temperature can be held at that point by regulating the supply of water to the cylinder jacket by means of the valve provided for that purpose. The pump, piping and water jacket of the engine must be drained when engine is not in use to prevent freezing and cracking of cylinder.

1036. Fuel for oil engine must be strained at the time storage tank is filled. In some types of engines fuel is injected into cylinder through a spray nozzle. Irregular operation may be caused by foreign matter in the oil sticking in the spray nozzle or in the check valve in the injector pump. The small hole in end of spray nozzle must be cleaned occasionally.

1037. Hot bearings will result from friction due to tight bearings, lack of lubrication and loose bearing causing bearings to pound hot.

1038. To correct a hot bearing, adjust bearing carefully to eliminate unnecessary friction and pound. The bearing must be properly lubricated. Water may be used on the bearing to keep the heat below the danger point until it has become properly seated. Excessive heat will cause the bearing to expand and stick.

1039. Too much oil must not be allowed in the cylinder, as this will result in a slow burning mixture being formed which does not develop the power that a proper explosive mixture does, causing incomplete combustion and formation of carbon.

1040. Carbonization is chiefly due to insufficient heat in the combustion chamber and may be caused by an overloaded engine using more oil than the heat from the combustion chamber can vaporize. It is important to prevent carbonization that the piston rings be a perfect fit to the cylinder walls, to prevent the loss of compression and power. Should the piston rings become stuck in the grooves, they must be soaked with kerosene, loosened up, and grooves carefully cleaned.

1041. To reseat valves, grind with emery and oil by revolving valve on seat until it will hold compression, carefully clean both valves and seat before starting engine.

1042. Knocking may be caused by loose crank brasses, piston brasses or bearing. Loose piston rings cause a knock in the cylinder which is sometimes very hard to locate. Pre-ignition will also cause knocking in the cylinder.

1043. Pre-ignition may be caused by an overload on the engine, by ignition of carbon deposits on cylinder walls and head and by the cylinder being too hot.

1044. The principal causes contributing to the rapid deterioration of internal combustion engines are lack of proper lubrication and absence of cooling water on the jacket. Pumper must give these features proper attention.

Electric Motors

1047. Motor, control and pump must be inspected at least once each week, at which time all parts must be thoroughly cleaned, and all contacts carefully inspected to see that they make and break at proper time and that contact surfaces are clean. All wearing parts must be well lubricated and special attention given to motor bearings. Building where motor is located must be kept clean. No papers or oily waste must be allowed to collect in switch boxes, near motor or near any electrical contact or wires.

1048. Waste must not be used around commutator or brushes, and gasoline or emery paper must not be used to clean commutator. If motor sparks excessively the proper official must be notified.

1049. Motor must be watched carefully for overheating. The commutator must not be allowed to become worn or grooved by the brushes.

1050. Any displaced wire must be reported. No attachments must be made to the wiring, as serious damage may be done to the equipment and there is danger of personal injury. A fuse must never be replaced with anything but a proper fuse. If one of a higher ampere rating is used it may cause serious damage to the motor. The fuse is the electrical safety valve and must no more be tampered with than a steam safety valve. A test lamp must be used to find blown fuses, thus avoiding chances of electric shocks. A gage must be applied to each alternating current motor to test the space between motor and field poles. If gage will not pass freely the bearings need immediate attention.

1051. On pump motors controlled from a distance, the remote control starter located in the pumphouse must be inspected and tested frequently to see that it starts the motor properly. Any badly burned contact must be reported.

1052. To start a direct current motor, move the arm of starter slowly over contacts from the "off" to the "on" position as the motor comes up to speed.

1053. An alternating current motor is usually started with an autostarter, the lever of which is usually thrown first to the starting position and held until motor has attained normal speed and then to the running position.

1054. The commutators on a direct current motor must be cleaned with a rag moistened with signal oil or kerosene.

1055. A fried or charred appearance of the insulations of the windings, especially the armature, indicates that the motor is overheated.

1056. The proper temperature of the motor is indicated when the two field coils and armature are not too hot to be comfortable to the hand after the motor has been running an hour.

1057. Motors must be lubricated once a month. Motors must be lubricated by draining oil from the boxes, cleaning the boxes and refilling with clean oil.

Water Softeners

1058. Directions for testing water and instructions on the operation and care of the treating plant shall be issued and must be kept posted in the plant and strictly adhered to.

Reading and Testing Meters

1059. Employee must make sure water meter is registering before attempting to read it.

1060. Employee must note the values of the unit on each dial and that one complete revolution of the pointer is equal to one division on the dial of next higher value.

1061. To test meter, employee must weigh the water delivered through one complete revolution of the pointer on the first dial of the meter, allowing sixty-two and five-tenths pounds to the cubic foot of water registered. If this method is impracticable meters may be tested in place by using a hose or pipe from the outlet of meter to a test meter of known accuracy.

RULES FOR INSPECTION OF BUILDINGS

General

1300. The inspection and maintenance of all buildings will be under the direct supervision of the ...., who will be responsible for the proper upkeep.

1301. The .... shall personally inspect every building in his district at least once each year.

1302. As many competent inspectors, who are familiar with general building construction and maintenance and who have a knowledge of good practice, as may be necessary to properly cover the district will be assigned to this inspection under the direct supervision of the ....

1303. These inspectors shall forward to the .... in {duplicate triplicate} on the prescribed form, a report of each building or structure inspected, stating in detail the condition found, covering, however, only parts of work requiring repairs or renewals. One of these forms shall be forwarded for each building inspected, shall be complete in itself, showing actual conditions found, regardless of previous report. Report shall be forwarded at the close of each day's inspection.

1304. The .... shall examine these reports, and if any defects of a serious nature are reported, take immediate steps to make necessary repairs. After the .... examines the reports he will send one copy to his superior officer, calling particular attention to the serious defects, advising action taken for correction, and also to the defects which are not serious but are sufficiently urgent or important to warrant the attention of such officer.

1305. The .... shall make a personal inspection of each building or structure at least once each year; shall examine the inspection reports forwarded him by subordinates, keeping his immediate superior officer promptly informed of any defects which require attention. He shall make recommendations to his superior officer of the work to be done to remedy conditions or to make permanent improvements. He shall at regular intervals make report to his superior officer on the prescribed form covering results of Division Inspectors' reports, state action taken to remedy defects or make recommendations to cover such work. He shall frequently examine his card index to become familiar with the condition of the buildings under his charge. He shall furnish annually a report to his immediate superior officer, stating the condition of each building and other structure on his territory.

1306. The .... and his subordinates shall be thoroughly familiar with the condition of all buildings and structures under their immediate charge.

1307. At least once each year a general inspection shall be made by the head of the department or his representative, who is directly responsible for the maintenance of buildings and structures. From this inspection, a program of all work necessary during the ensuing year to keep the buildings in safe, sanitary and presentable condition will be prepared.

Field Inspection

1308. Division Building Inspectors will report to and receive instructions from the .... In selecting inspectors, particular attention shall be given to their judgment, previous experience and familiarity with the buildings in the district to which they are to be assigned.

1309. It shall be the duty of the Division Building Inspector to inspect all buildings and structures in his district other than bridges, trestles and track structures.

1310. The Division Building Inspector shall at the close of each day send to the .... a report on the prescribed form in $\left\{\begin{matrix}\text{duplicate}\\ \text{triplicate}\end{matrix}\right\}$ showing defects, if any, giving a clear description of the defects in sufficient detail so that materials for correction may be ordered, if the case be urgent. Every part of the structure must be examined from foundation to roof, inclusive. Special attention must be given to the inspection of foundations and roofs, to heating and plumbing appliances and such facilities as may through lack of proper upkeep cause accidents, loss in time or money or serious inconvenience to the public. In the event that the entire structure is found in good condition, a check mark on the report in space provided for the purpose is all that will be required and no details need be given. Each report shall cover only a single structure and shall be filled in on the form as soon as the inspection is completed.

1311. Careful inspection shall be made of the steel roof construction in all locations where soft coal gas is prevalent, as in engine houses, boiler and smith shops, train sheds, etc.

Records

1312. The .... upon receiving reports from the Division Building Inspector, after carefully examining same shall have the information entered on a card index file. This index file should have guide cards for each location and class of structure and sufficient data cards back of each guide card on which to copy essential information from the Division Inspector's reports.

1313. The location guide card shall show "Location or Milepost," Division, Valuation Section and Number.

1314. The guide cards for various classes of buildings shall be of different colors, for "Stations and Office Buildings," "Roadway Buildings," "Shops and Engine Houses," etc.

1315. The inspection data cards shall show the name of building, location, number, date erected, general dimensions, character of construction (i. e., frame, brick or concrete, etc.) and have sufficient space in which to write the important facts shown on the inspection forms; one or more cards being used for a building as the case may require.

RULES FOR INSPECTION OF BRIDGES, TRESTLES AND CULVERTS

General

1350. The inspection and maintenance of all bridges, trestles and culverts will be under the direct supervision of ...., who will be responsible for their safety.

1351. The .... shall personally inspect every structure at least .... each year.

1352. One or more competent bridge inspectors who are familiar with strength of wooden structures and have a general knowledge of steel, stone and concrete work will be assigned for the inspection of bridges under the direct supervision of the........................

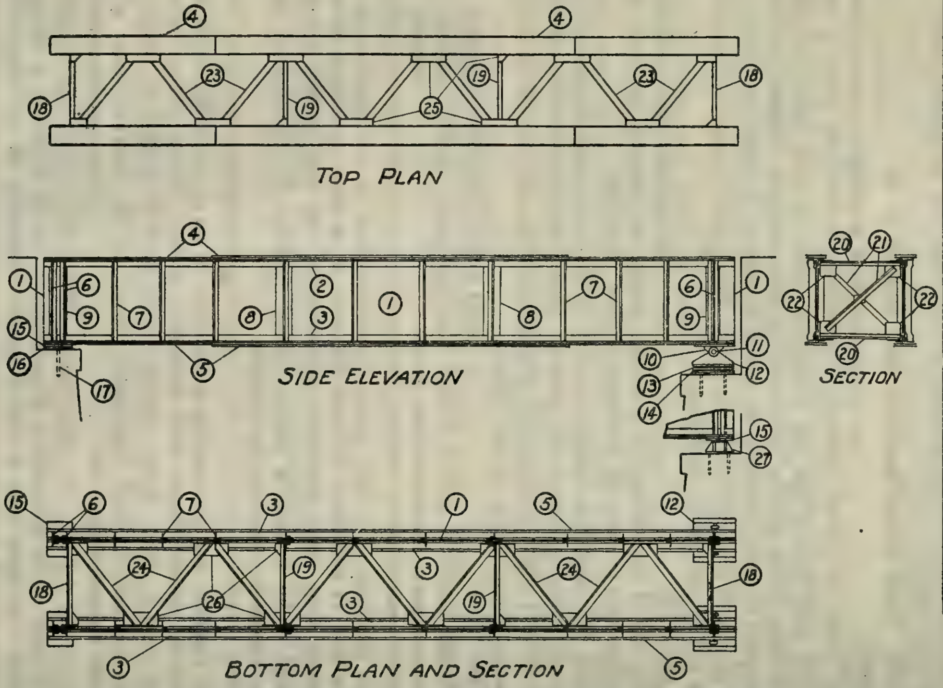
1353. These bridge inspectors shall forward to the .... in {duplicate / triplicate} .... on the proper form provided, a report of each bridge, trestle or culvert inspected, enumerating in detail the parts of each structure inspected, giving the conditions found in each individual part. One of these forms must be forwarded for each structure inspected, and shall be complete in itself, showing the actual conditions as found, regardless of what may have previously been reported. These reports must be forwarded at the end of each day's inspection.

1354. The .... shall examine these inspection reports, and if any defects of a serious nature are reported he shall take immediate steps to make the necessary repairs. After the .... examines the inspection reports he will forward one copy of each of the bridge inspection reports to his superior officer, calling particular attention to any defects which are not of an emergency nature, but are serious enough to warrant the attention of such officer.

1355. The .... shall make a personal inspection of each bridge, trestle or culvert at least once each year. He shall examine the inspection reports forwarded him by the ...., keeping his immediate superior officer promptly informed of any defects discovered which require attention. He shall make recommendations to his superior officer with a plan, if necessary, to cover the work to be done to remedy various conditions or to make permanent improvements. He shall furnish annually a report to his immediate superior officer showing the condition of each bridge, trestle or culvert on his division.

1356. The .... and his subordinates should be thoroughly familiar with the capacity and stability of all of the bridge structures, trestles and culverts under their immediate charge. If any serious defects should develop which, in his opinion, would serve to weaken the structure of any member, he shall immediately report to his superior officer after personal inspection with his ...., giving recommendations to remedy the defects. He might request, if necessary, that a special inspection be made of the structure by a representative of the Engineer of Bridges.

1357. At least once a year a general inspection of all bridges and structures shall be made by the head of the department or his representative,

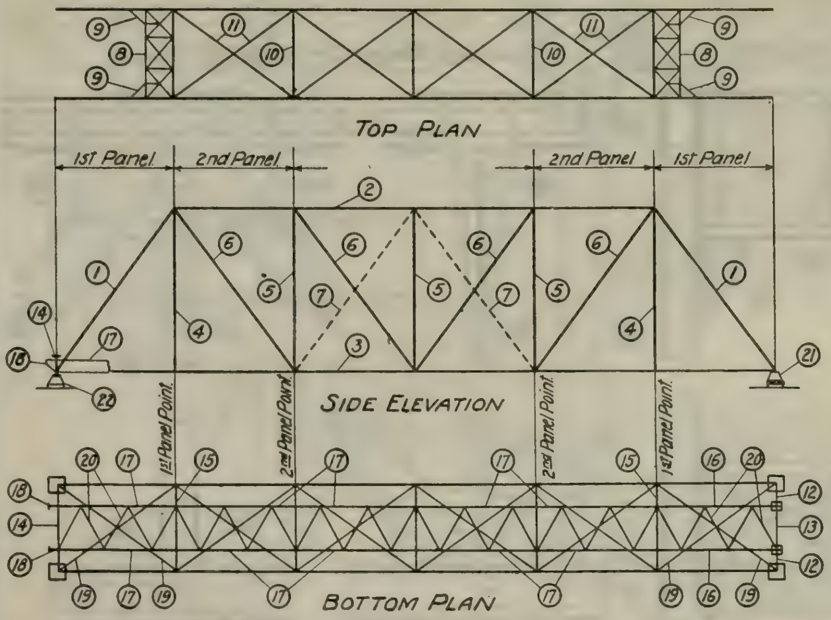


Note,-Where sufficient information cannot be given by description furnish sketch.

LEGEND

No.	Description	Location of Individual Members.
1	Web Pl.	Number from E. or W. End, N. or S. Gir.
2	T. Flng. ∠.	Inside or Outside, N. or S. Gir.
3	B. Flng. ∠.	Inside or Outside, N. or S. Gir.
4	T. Cov. Pl.	Number from Flng. ∠'s, N. or S. Gir.
5	B. Cov. Pl.	Number from Flng. ∠'s, N. or S. Gir.
6	E. Stiff. ∠.	Number from E. or W. End, Ins. or Outs, N. or S. Gir.
7	I. Stiff ∠.	Number from E. or W. End, Ins. or Outs, N. or S. Gir.
8	Web Spl. Pl.	Number from E. or W. End, Ins. or Outs, N. or S. Gir.
9	Fill.	State Stiff. under which Fill. occurs.
10	T. Pin Shoe.	E. or W. End, N. or S. Gir.
11	Pin.	E. or W. End, N. or S. Gir.
12	B. Pin Shoe.	E. or W. End, N. or S. Gir., Fix. or Exp. End.
13	Rlr. Nest.	E. or W. End, N. or S. Gir.
14	Rlr. Bed Pl.	E. or W. End, N. or S. Gir.
15	S. Pl.	E. or W. End, N. or S. Gir.
16	Mas. Pl.	E. or W. End, N. or S. Gir.
17	A. Bolts.	
18	E. X. Frm.	E. or W. End.
19	I. X. Frm.	Number from E. or W. End.
20	Hor. X. Frm. ∠.	State X. Frm. in which ∠ occurs, T. or B.
21	Diag. X. Frm. ∠.	State X. Frm. in which ∠ occurs.
22	Gus. Pl.	State X. Frm. in which Pl. occurs, T. or B, N. or S. Gir.
23	T. Lat. ∠ or Rd.	Number from E. or W. End.
24	B. Lat. ∠ or Rd.	Number from E. or W. End.
25	T. Lat. Pl.	Number from E. or W. End. N. or S. Gir.
26	B. Lat. Pl.	Number from E. or W. End. N. or S. Gir.
27	Shoe	E. or W. End, N. or S. Gir.

NAMES OF MEMBERS IN DECK PLATE GIRDER SPANS

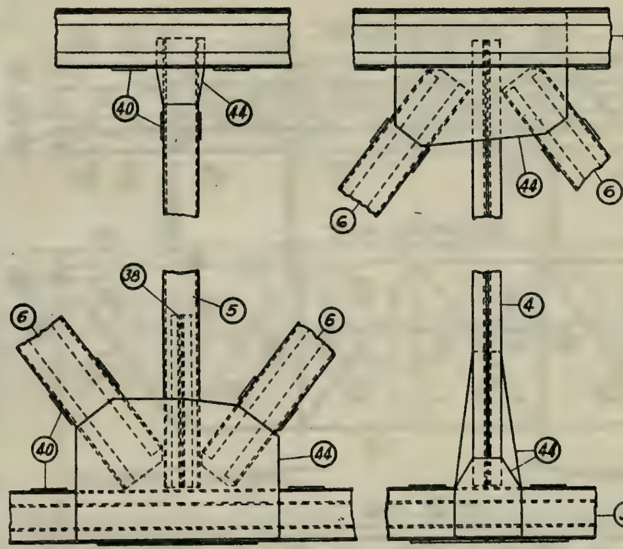


Notes,- Names of Members in Deck Truss Spans similar to those given for Through Truss Spans.
Where sufficient information cannot be given by description furnish sketch

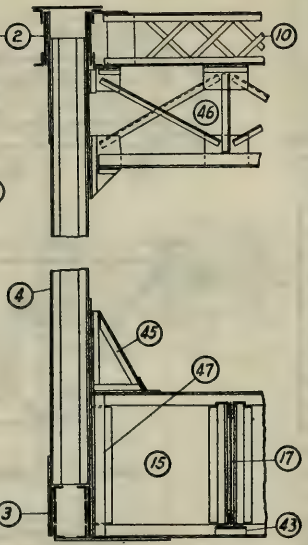
LEGEND		
No.	Description	Location of Individual Members.
1	E.P.	E. or W. End, N. or S. Truss.
2	T. Chord.	State Panel from E. or W. End, N. or S. Truss.
3	B. Chord.	State Panel from E. or W. End, N. or S. Truss.
4	Hanger.	State Panel Point from E. or W. End, N. or S. Truss.
5	I.P.	State Panel Point from E. or W. End, N. or S. Truss.
6	Diag.	State Panel from E. or W. End, N. or S. Truss.
7	Counter.	State Panel from E. or W. End, N. or S. Truss.
8	Ptl.	E. or W. End.
9	Ptl. Bkt.	E. or W. End, N. or S. Truss.
10	T. Strut.	State Panel Point from E. or W. End.
11	T. Lat.	State Panel from E. or W. End.
12	E. Strut.	E. or W. End, N. or S. Side
13	E.X. Frm. or Strut.	E. or W. End.
14	E.F. Bm.	E. or W. End.
15	I.F. Bm.	State Panel Point from E. or W. End.
16	E. Str.	E. or W. End, N. or S. Side.
17	I. Str.	State Panel from E. or W. End, N. or S. Side.
18	E. Str. Bkt.	E. or W. End, N. or S. Side.
19	B. Lat.	State Panel from E. or W. End.
20	Str. Lat.	Number E. or W. of Panel Point from E. or W. End
21	Ex. Shoe.	E. or W. End, N. or S. Truss.
22	Fix. Shoe.	E. or W. End, N. or S. Truss.

Note,- For names of detail parts see,-
"Names of Members in Through Pin Truss Spans."
"Names of Members in Through Rivited Truss Spans."
"Names of Members in Through Plate Girder Spans."

NAMES OF MEMBERS IN THROUGH TRUSS SPANS



TYPICAL DETAILS AT PANEL POINTS.



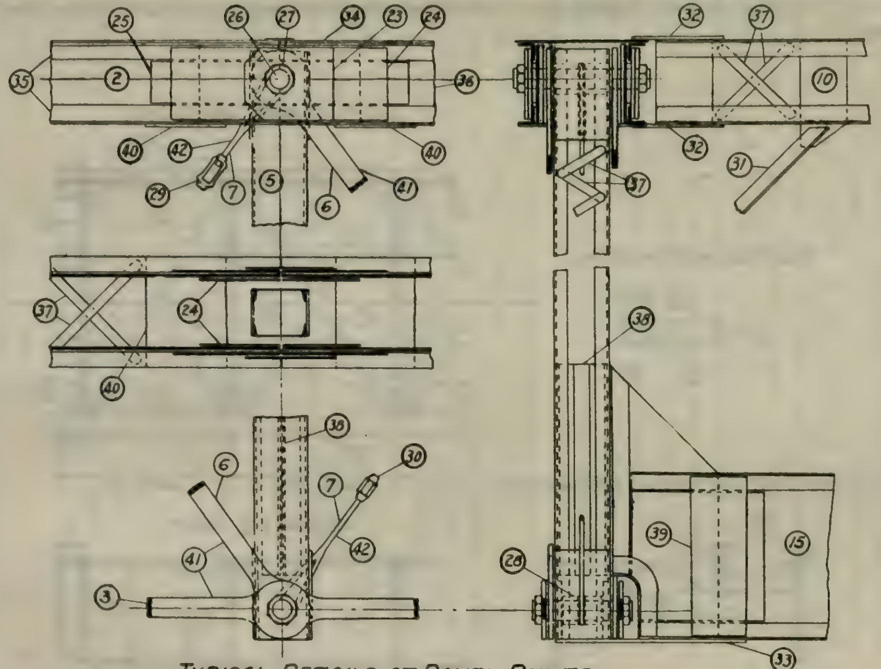
SECTION.

LEGEND

No.	Description	Location of Individual Members.
2	T. Chord.	For Location see,-"Names of Members in Through Truss Spans.
3	B. Chord.	
4	Hanger.	
5	I.P.	
6	Diag.	
10	T. Strut.	
15	I.F. Bm.	
17	I. Str.	
38	Diaph.	State on which member and where located.
40	Tie Pl.	
43	Shelf L.	
44	Gus. Pl.	State Panel Pt. from E. or W. End, N. or S. Truss, Ins. or Outs
45	F. Bm. Bkt.	State F. Bm. to which Bkt. is attached, N. or S. End
46	Sway Frm.	State Panel Point from E. or W. End.
47	Con. L.	State on which member and where located.

NAMES OF MEMBERS IN THROUGH RIVETED TRUSS SPANS

Note,- Where sufficient information cannot be given by description furnish sketch.

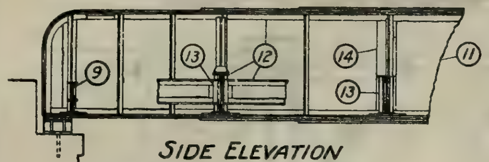


TYPICAL DETAILS AT PANEL POINTS

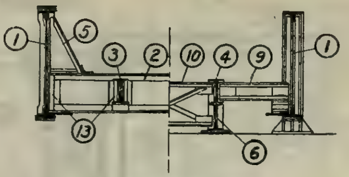
Note.- Where sufficient information cannot be given by description furnish sketch

LEGEND		
No	Description	Location of Individual Members
2	T.Chord.	For Location see;-"Names of Members in Through Truss Spans."
3	B.Chord	
5	I.P.	
6	Diag.	
7	Counter.	
10	T.Strut.	
15	I.F.Bm.	
23	Jaw Pl	State on which member and where located.
24	Pin Pl.	
25	Fill.Pl.	
26	Pin.	State Panel Pt. from E. or W. End, N. or S. Truss, T. or B. Chord
27	Pin Nut.	State Pin on which Nut occurs, Ins. or Outs
28	Pack. Ring.	State Pin on which Pack. Ring occurs.
29	Turnbuckle	State Member on which Turnbuckle occurs.
30	Sleeve Nut.	State Member on which Sleeve Nut occurs.
31	Knee Brace	State Member to which Knee Brace is attached
32	T.Lat.Pl.	State Panel Pt. from E. or W. End; N. or S. Truss, T. or B.
33	B.Lat.Pl.	State Panel Pt. from E. or W. End, N. or S. Truss.
34	Cov. Pl	State on which member and where located.
35	Flng. L	
36	Web Pl	
37	Lattice Bar.	
38	Diaph	
39	Spl. Pl.	
40	Tie Pl.	
41	Eye Bar.	
42	Loop Rd	

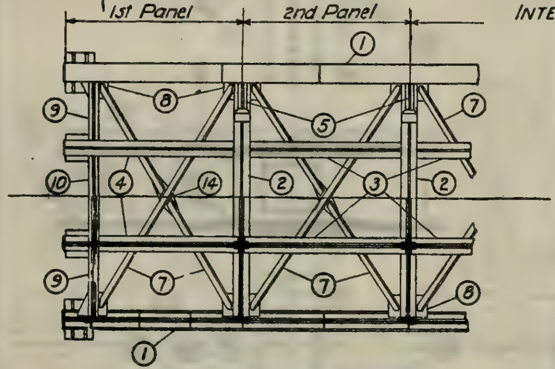
NAMES OF MEMBERS
IN
THROUGH PIN TRUSS SPANS



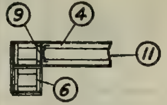
SIDE ELEVATION



INTERMEDIATE AND END SECTIONS



TOP PLAN AND SECTION



END STRINGER PEDESTAL

LEGEND

No	Description	Location of Individual Members.
1	Main Gir.	N. or S.
2	F. Bm.	Number from E. or W. End.
3	I. Str	State panel in which Str. occurs, N. or S.
4	E. Str.	E. or W. End, N. or S.
5	F. Bm. Bkt.	State F. Bm. to which Bkt. connects, N. or S.
6	Str. Ped.	State E. Str. which Ped. supports.
7	Lat. L or Ra	State Panel from E. or W. End.
8	Lat. Pl.	Number from E. or W. End, N. or S. Gir.
9	E. Strut.	E. or W. End, N. or S. Side
10	E. X. Frm.	E. or W. End.
11	Web Pl.	State on which member and where located.
12	Flng. L	
13	Con. L	
14	Spl. Pl.	

Note.- For names of parts not numbered compare "Names of Members in Deck Plate Girder Spans"

NAMES OF MEMBERS IN THROUGH PLATE GIRDER SPANS

Note.- Where sufficient information cannot be given by description furnish sketch.

who is directly responsible for the maintenance of these structures. From this inspection, a program of all work which will be necessary during the ensuing year, in order to maintain the structures in safe condition, will be prepared. This inspection will afford all officers in direct charge of this character of work an opportunity to familiarize themselves with the detail work to be done during the next season.

Field Inspection

1358. Division Bridge Inspectors will report to and receive instructions from .... In the selection of the inspector, particular attention should be given to his judgment, activity and familiarity with the character of structures on the territory to which he is to be assigned. It shall be the duty of the Division Bridge Inspector to inspect all bridges, trestles, culverts and other openings of whatever character on his territory.

1359. The Division Bridge Inspector shall each day, after a structure is inspected, send to the .... a report on approved form in {duplicate triplicate} showing defects, if any, giving a minute description of said defects. Every part of both the super- and sub-structure (foundation and bridge) must be closely examined in detail. When no defects are found the report shall state—"Bridge in good condition. No defects found." A report for each separate structure inspected must be made each day, and each report must be complete in itself, and must show the actual condition of the structure as found, regardless of what has been previously reported. When defects are found which are of such a character as in the opinion of the inspector endanger traffic at regular speed, trains must be flagged and only allowed to pass over the structures at such speed as the inspector may consider safe.

Immediately after the inspector has taken steps to protect traffic, he must notify at the nearest telegraph or telephone station the Train Dispatcher with copy to the .... and Superintendent, giving necessary information briefly as to safe speed of trains over the structure until permanent repairs are made. He shall follow this immediately with a written report on the next train to the ...., giving in detail the defects found. The .... upon receiving reports from the Division Bridge Inspector, after carefully going over same, shall forward one copy to the .... In the .... office there should be provided a card index file upon which should be entered, periodically, the reports of the Division Bridge Inspector.

1360. In order to reduce the amount of detail work in writing up these reports the following abbreviations are permissible in order to condense the report without destroying its effectiveness:

A.	Anchor	Diaph.	Diaphragm
B.	Bottom	E.	End
B. W.	Back wall	E. end	East end
B. S.	Bridge seat	W. end	West end
Bkt.	Bracket	E. B.	Eastbound
Bm.	Beam	Ex.	Expansion
Con.	Connection	F.	Floor
Cov.	Cover	Fill.	Filler
Diag.	Diagonal	Flng.	Flange

Fnd.	Foundation	Packin.	Packing
Frm.	Frame	Ped.	Pedestal
G. R.	Guard rail	Pl.	Plate
Gen. Con.	General Cond.	Ptl.	Portal
Gir.	Girder	Rd.	Rod
Gus.	Gusset	Rlr.	Roller
Hor.	Horizontal	S. Pl.	Sole plate
I.	Intermediate	Spl.	Splice
In.	Inner	Stiff	Stiffener
Ins.	Inside	Str.	Stringer
L.	Angle	T.	Top
Lat.	Lateral	U. C.	Undercoping
Mas.	Masonry	W.	West
O.	Outer	W. B.	Westbound
Outs.	Outside	W. W.	Wing wall
P.	Post	X.	Cross

WOODEN STRUCTURES

1370. The Division Bridge Inspector shall examine all wooden bridges and trestles.

Points to be Examined:

(a) Approaches—for surface and line and ballast section.
(b) Decks—for rail spiked in accordance with standards with full bearing on each tie, particularly where ties are renewed out of face; inside guard rails placed in accordance with standards; guard timber for soundness and projection of guard rail bolts above top of running rail.
(c) All members—boring where it seems necessary in order to determine definitely interior conditions.
(d) Splices.
(e) Bearing at ends of members for decay or crushing.
(f) All members—see that they are in place, straight and sound.
(g) Angle blocks—for breaks or cracks.
(h) Gib plates—noting bearing on timber.
(i) Rods—noting if they are in adjustment.
(j) Bents and trestles—noting if they are plumb and have transverse and longitudinal bracing.
(k) Piles—when used.
(l) All other parts of structure not specifically mentioned in this paragraph.

1371. The Division Bridge Inspector must report any odd sizes of lengths of timber found in the structure which are not standard or any new work which has been done not conforming with standards.

1372. When the adjustment or replacement of a member is necessary, it must be done under the personal supervision of the .... or his representative.

1373. The Division Bridge Inspector shall examine the property underneath and adjacent to the structure and report any fire hazard, weeds, dead grass, vines, drifts, etc., that should be removed. He must also report the condition of the fire protection equipment.

STEEL STRUCTURES

1380. The Division Bridge Inspector shall examine all steel structures.

Points to be Examined:

(a) Deck

Size, spacing and depth of ties over supports.
Uniformity of bearing of ties.
Condition of timber as to defect and decay.
Number and size of defective ties, guard timbers, and guard rails.
Fastenings of ties.
Fastenings of guard timbers and guard rails.
Size of tie plates.
Condition of walks and rails.
Condition of planking between rails and between tracks.
Condition of refuge bays.
Condition of ballasted deck.
Whether waterproofing is effective or requires repairs.

(b) Fire Protection

Description and condition of fire protection.

(c) Track

Condition of rails, joints, and fastenings.
Alinement of track and its relation to the steel structure.
Surface of track on bridge and on approaches.
Where the track is out of line or surface, the report shall show the location, amount, and probable causes.

(d) Shims and Blocking

Condition of shims and blocking, giving description and location, making sketch if necessary.

(e) Bridge Seats

Condition as to defects and cleanness.

(f) Anchors and Bearings

Whether the superstructure is securely anchored to the masonry.
Whether bed plates, rollers, and pedestals are clean, in correct position, and have full bearing.
Whether rollers are operating properly.
Whether there are any flaws or breaks in bearings.

(g) Expansion

Clearance between expansion ends and masonry on adjoining spans.
Whether there is any apparent movement of the masonry.

(h) Paint

Condition of paint.
Date of last painting, number of coats and kind of paint, as stenciled on the bridge.
Whether spot painting or repainting is necessary.

(i) Straightness and Alinement of Members

Condition of individual members as to bends and kinks.
Camber of trusses.
Alinement of trusses, girders, floor members, and towers.
Adjustment of eye-bars and counters.

(j) Damage from Blows

Parts damaged by blows from equipment, lading or floating objects.
Location and extent of damage, making sketch to show parts damaged and repairs suggested.

(k) CRACKS AND BREAKS

Cracks and breaks, especially in floor connection angles, hangers, pin plates, fillets of angles of flanges and posts, and in end sections of lower chords or flanges over or near bearings.

(l) PINS, PIN HOLES, AND NUTS

Conditions of pins and pin holes, as to movement and wear.

Pins should be observed under traffic if practicable. The report shall give the location of the pins observed, the amount of movement of the pins, and the wear of pins and pin holes if it can be determined.

Whether pin nuts are tight.

(m) RIVETS AND TURNED BOLTS

Location and number of rivets and turned bolts that are loose and of rivets that have badly corroded heads, giving special attention to floor connection.

(n) CORROSION

Condition of members as to loss of section from corrosion, noting extent of such action, with measurements of remaining section if members are badly corroded.

(o) CLEANNESS

Collection of dirt on horizontal surfaces.

(p) MOVABLE BRIDGES

1. Lubrication

Whether a lubrication chart is posted and the instructions on it are followed.

Whether moving parts have been kept sufficiently lubricated. They should be observed during operation. The report shall show whether lack of lubrication is due to inattention or to inadequate facilities. If facilities are inadequate, complete information shall be given with recommendation for improvement.

2. Gears

Condition of gears as to:
Accurate meshing.
Fit on shafts.
Fit on keys.
Breaks, flaws, and excessive wear.
Protection against falling objects.
Cleanness.

3. Bearings

Whether bearings have proper linings and good running fit.

Whether shafting is accurately alined and whether collars and thrust bearings are in adjustment.

Attachments of caps to bases and of bearings to supports.

Alinement, fit, and wear of trunnions and trunnion bearings.

4. Castings.

Condition of wedges, sheaves, locking devices, rollers, treads, etc., as to breaks, or flaws which might cause breaks.

5. Cables

Adjustment of cables as indicated by slackness, inclination of equalizer bars, or uneven seating of spans.

Condition of cables as to rust and excessive accumulations of hardened grease.

Broken wires and broken strands.

Condition as to lubrication.

Working clearances.

End connections and clamps.

6. Clutches and Brakes
   Working condition and cleanness.
7. Power Equipment
   Condition for delivering the necessary power.
   Whether properly maintained.
8. Mechanical Features
   Operating condition.
   Adjustment of balance wheels.
   Adjustment of wedges or other lifting devices.
   Entire turntable of swing bridges.
   Rail locks and signal interlocking connections.
   Navigation lights.
   Clearances through a complete cycle of operation.
   Balance through a complete cycle of operation.
   Safety devices—electrical and mechanical.
   Lightning protection of power plant and superstructure.
   Condition and adjustment of guides, centering devices, buffers, and bridge locks.
   Condition and fastenings of racks, tracks, and tread plates.
9. Counterweights.
   Condition of counterweights and their supports.
10. Operating Diagram
    Whether an operating diagram is posted.
11. Record of Openings
    Whether a complete record is being kept of bridge openings, vessel movements, and happenings affecting the interests of the Railway Company.

1381. The Inspector shall report indications of overload or failure in any part of the bridge. He shall observe the behavior of the bridge during the passing of live load, if practicable, noting excessive vibration, deflection, and side sway.

1382. Attachments of wires, pipes, etc., that may be harmful to the bridge shall be reported.

MASONRY AND COMPOSITE STRUCTURES

1390. The Division Bridge Inspector shall examine all masonry, concrete, and composite structures including masonry and concrete foundations of all structures.

Points to be Examined:

(a) The inspector shall first examine the structure for any indication of settlement or other movement. This may be shown by inequalities in the line or surface of the track or by improper space between the back walls and the ends of the supported superstructure.
(b) He shall watch the structure under passage of trains to see whether there is any movement in any joints or courses of masonry or any tipping or working of the structure as a whole.
(c) The pedestals and bridge seats shall be examined for indications of crushing or settlement or other movement.
(d) Expansion joints and bearing shall be examined to see that the movement is not restricted.
(e) Investigation shall be made for signs of undue weathering, disintegration, cracks, crushing, leakage, bulging or need of pointing.
(f) A careful inspection shall be made at the water or ground line for distintegration due to the action of water or ice.

(g) The inspection of foundations shall include an examination for indications of scouring or undermining and when necessary, soundings shall be taken for this purpose.

(h) In connection with the inspection of arches and culverts, sufficient examination shall be made to indicate the need for additional protection in the form of paving, inverts, apron walls or curtain walls.

(i) If definite and reliable records are not available, a field examination shall be made to determine the type and physical condition of the foundation.

(j) Soundings shall be taken to determine the relative elevation of the bed of stream and the bottom of the masonry.

(k) Attention shall be given to any signs of failure to arch rings as may be indicated by cracks or a flattening of the arch.

(l) Reinforced concrete structures shall be examined for any indications of leakage or softening of the concrete. Any instances in which the reinforcement is exposed or rust stains appear, shall be reported.

(m) The provisions for drainage shall be examined to see if they function properly.

General:

(a) The inspector shall, so far as possible, obtain the history of any defects in order to determine, if possible, the exact cause.

(b) In calling attention to defects, mention shall be made as to whether these have the appearance of recent development or whether they seem to be of long standing. The inspector shall compare condition with those recorded from previous inspections and report any change.

(c) In reporting cracks in masonry, the inspector shall state whether they have the appearance of surface checks or cracks which would indicate incipient failure. In the latter case, permanent marks shall be made on either side of the cracks and measurements taken so that developments can be accurately determined.

(d) When signs of settlement or movement are noted, lines and levels shall be run and reference marks established so that subsequent movement can be determined.

CULVERTS AND PIPES

1400. The Division Bridge Inspector shall examine all culverts and pipes.

Points to be Examined:

(a) General
    (a) Openings—noting if they are in good condition, clean and free of all debris.
    (b) Ends—noting if the water is undercutting or scouring.

(b) Masonry Culverts
    (a) Walls and roof—noting cracks, disintegration, crushing, leakage, bulging or need of pointing.

(c) Wooden Box Culvert
    (a) Roof and side walls—noting if there is any buckling, and, if size of culvert permits, if all timber is sound.

(d) Pipes
    (a) Settlement, cracking, or pulling apart of pipe.

(e) The Division Bridge Inspector shall report if there is need for additional protection in the form of paving, inverts, apron or curtain walls.

RECORDS

1410. The .... upon receiving reports from the Division Bridge Inspector, after carefully examining same shall have the information entered on a card index file. This index file should have guide cards for each location and class of bridge and sufficient data cards back of each guide card on which to copy essential information from the Division Inspectors' reports.

1411. The location guide card shall show "Location or Milepost," Division, Valuation Section and Number.

1412. The guide cards for various classes of bridges shall be different colors, as steel, wooden, composite, etc.

1413. The inspection data cards shall show the bridge number, location, date erected, character, etc., and have sufficient space in which to write the important facts shown on inspection forms; one or more cards being used for the bridge as the case may require.

*FORMS

1415. Form to be used by Division Bridge Inspector for general inspection of all bridges, trestles and culverts should be printed in books of 100 or more leaves, each leaf being perforated and having a carbonized back. The backs of the books should be stiff cardboard or linen and size should not exceed 4½ inches by 6½ inches.

MISCELLANEOUS RULES AND INFORMATION

HANDLING SCRAP AND REFUSE MATERIAL

Scrap and Refuse

2000. Wornout and unserviceable tools must be turned into the stores department, according to instructions.

2001. Salvageable scrap will be picked up and stored at designated points for disposition.

2002. Track ties, head blocks and switch ties removed should be piled adjacent to the track and culled before final disposition.

2003. Material and rubbish from repairs of bridges, buildings, trestles, culverts, telegraph lines, fences, etc., must be cleaned up as soon as the work is completed. Material of a usable nature must be placed in a convenient pile for loading. If rubbish is burned see that the fire is at a safe distance from all structures.

2004. Material piled for inspection or loading must be placed at a safe distance from the track.

2005. Rubbish and waste from station grounds, buildings and freight houses which cannot be burned should be buried or otherwise disposed of as directed.

2006. In burning refuse when incinerators are not available the fire must not be left unattended or started unless sufficient force is at hand for keeping it under control. The fire must be put out before leaving.

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*Forms not yet submitted.

HANDLING EXPLOSIVES

Dynamite

2025. Danger signs must be conspicuously placed on all buildings and magazines in which explosives are stored. The Supervisor must be familiar with the state and federal laws and local regulations covering the transportation and storage of explosives. He must see that these requirements are understood and obeyed by the employee delegated to handle the explosive to be used.

2026. Dynamite, powder and other explosives shall be stored in fireproof magazines located at a safe distance from the company buildings, or buildings and property of others, in accordance with the law, and where they are not liable to be interfered with.

2027. The supply in storage should be kept at the minimum for the requirements and be removed in small quantities as needed.

2028. Fuses and caps must in no case be stored in the same building with explosives.

2029. No man should be assigned to the handling of these explosives who is not able to satisfy the Supervisor of his qualifications and previous experience in their use.

2030. Employees must not strike or light matches while handling explosives. An employee shall not carry a lighted candle or other fire while handling dynamite or other explosive supplies. No explosives may be brought within five feet of any lantern or enclosed fire.

2031. Under no circumstances may an employee permit dynamite, detonators or other explosives he may be handling to be placed near a fire or within range of flying sparks even though the explosive is packed in a strong tight box.

2032. When frozen, dynamite may fail to explode or explode with little force, and in either case a whole or part of the charge may be left in the "bore" hole or mixed with broken rock or dirt. Such dynamite is liable to explode if struck with a shovel or other tool and cause personal injury or loss of life.

2033. Dynamite is likely to freeze when its temperature falls below 50 degrees Fahr. and dynamite of such temperature must be considered as frozen and thawed before using.

2034. Dynamite may be thawed by using an approved kettle or by placing it in a tight box and burying it in fresh manure.

2035. In thawing dynamite with an approved kettle: First, fill the water compartment with water of such temperature that it will not be higher than 100 degrees Fahr. when the dynamite is put in the compartment provided for it. Second, place the dynamite in the compartment provided for it after ascertaining that the compartment is clean and dry.

2036. Do not place dynamite in the kettle when the temperature of the water is above 100 degrees Fahr.

2037. Do not place the thawing kettle near a lighted lantern or a fire of any kind.

Inflammable Oils

2050. All gasolines evaporate rapidly in hot weather, but even in the coldest weather gasoline gives off inflammable vapors in sufficient amount to ignite readily. This vapor is heavier than air and tends to form a layer along the ground and only mixes slowly with the air.

2051. Gasoline and other similar fuels for use in pumping plants, motor cars, etc., must be kept in tanks buried in the ground and properly ventilated. These tanks must never be filled by open lamp or torch light. Lighted matches, pipes or cigarettes must be kept away from these tanks.

2052. Oil-soaked rags or waste often cause spontaneous combustion. Do not allow these to accumulate.

2053. Fusees, torpedoes or matches must be kept or carried only in containers provided for their protection.

2054. Do not use water on an oil fire. Smother if possible with dry earth, steam or wet blankets.

2055. In case of wrecks involving tank cars of inflammable oils the Section Foreman should be specially careful to:

(a) Police the location.
(b) Cause the removal or prevent the approach of all lights or fires other than closed electric lights.
(c) Keep all unauthorized persons away.

PROCEDURE IN CASE OF ACCIDENT

General

2100. When an accident has occurred the most important point is that someone must take upon himself the direction of affairs. If you are the employee of highest rank on the ground, take command at once.

2101. Immediately send a reliable person to get in touch with the nearest Company's surgeon. Should the need of surgical aid be very urgent, summon any surgeon who can arrive the quickest, at the same time notifying the Company's surgeon.

2102. In the meanwhile, designate those who are to minister to the injured, selecting men you know to be best qualified.

2103. Spectators will crowd around, depriving the injured man of air and hindering you with their advice and comments. Make them stand back at a distance, well out of the way.

2104. Do not permit whiskey or other alcoholic liquor to be given the patient while under your direction.

2105. If local fire department is available, material assistance can be rendered by them, if called. Do not hesitate to call on them for aid.

Accidents

2125. All telegraphic calls for surgeons will have precedence over all other business, except train orders.

2126. In cases of injuries to passengers or employees requiring surgical aid, the surgeon of the Company who can reach the point the quickest must be immediately called by the officer in charge. If impossible to secure immediate attendance of Company's surgeon, other surgical aid should be promptly secured to attend until the arrival of the Company's surgeon. Upon arrival of Company's surgeon, he shall assume charge of the situation, making proper arrangements with the surgeon already in attendance for continuance, or discontinuance, of services.

2127. When a number of persons are injured, the services of competent surgeons in the vicinity should at once be secured and every attention given the wounded. Company's surgeons must be immediately notified, giving number of persons injured, and what probably will be required for their relief.

2128. The Company will not be responsible for the employment of other surgeons than those above named, and no obligation of any kind, beyond the services required while awaiting the arrival of the Company's surgeon, or subsequently arranged by him, must be assumed for the Company.

2129. The officer in charge will arrange to have the injured persons removed from the scene of the accident as promptly as possible, providing an ambulance or other conveyance, and sending a man or men with the injured persons, when necessary; any expense incurred to be billed direct to the Company, or paid by the person in charge, who will present a statement of same and receive voucher.

2130. No important surgical operation should be performed previous to the arrival of Company's surgeon, except such as may be required for the immediate safety of the patient.

2131. While the Company's surgeons will be assigned to duty within prescribed limits, they will be expected to go out of such limits whenever required.

2132. Employees will be expected, whenever able, to visit the Company surgeon's office for treatment, except where their residence is remote therefrom.

2133. Emergency cases, directions for the use of which are contained therein, will be carried on all trains and at all important shops and stations.

2134. Employees who witness or have any knowledge whatever of an accident, should refrain from giving information to the injured person or anyone else except the Company's officers and claim agents, unless legally required. Persons seeking information should be referred to the Claim Agent or other official of the Company.

2135. It is the desire of the Company that all statements in reference to personal injury accidents should be as full as possible and that all facts whether favorable or unfavorable to the injured person, the Company or its employees should be stated.

FIRST AID TO THE INJURED

Shock

2150. After a painful injury, the person will be greatly prostrated, more or less dazed; his face pale and covered with cold sweat, pulse and breathing weak. He is suffering from shock, which will be severe in proportion to the severity of the injury. The best thing to give him is a half or a whole cup of strong black coffee or tea, or even hot water slowly swallowed. Lay him flat on his back with head low. The coldness of his body-surface indicates that all blood is driven to the internal organs. You must return it to the natural channels. Wrap him in warm blankets.

Apply bottle filled with hot water, or heated bricks, everywhere about his body and limbs, taking care that you do not burn his skin.

Examination

2155. In order to relieve the suffering of an injured person, you will first have to ascertain the extent of his injury. It may be found necessary to remove some portion of the clothing, which often cannot be done in the usual way, because the slightest movement of the body would greatly increase suffering. With your pocket knife cut off the trousers, coat and shirt by ripping up the seams, but the underclothing must be cut or torn off the easiest way, and likewise the shoes, when a foot is badly crushed. You will generally find a bleeding wound that will call for first attention.

Hemorrhage or Bleeding

2160. Do not forget that exposure of the wound to the air, especially if, at the same time, you elevate the injured part as high as you can get it, is all that is necessary to stop bleeding in a large majority of cases. Pressure of a firm bandage directly upon the bleeding should also be tried.

2161. Should these means fail to stop the bleeding after several minutes' trial, you will have to make pressure upon the blood vessels through which the flow is coming toward the wound. The blood flows from the heart, through the vessels, precisely as water flows from the hydrant through your garden hose. If the water is streaming through a break in the hose, the escape can be stopped by pressure on the hose between the break and the hydrant. In the same way you can stop bleeding from a wound by making pressure on the blood vessels somewhere between the bleeding point and the heart.

2162. In the arm and leg the vessels are buried among the muscles, hence to bring pressure to bear upon them you will have to tie a strong bandage, a handkerchief, rope, strap or similar article tightly around the limb. An article thus employed is called a "constrictor," because it constricts or squeezes close together all the parts within its embrace.

2163. Above the elbow and above the knee there is one bone. The blood vessels lie close to this single bone, and you can compress them with ease between the constrictor and the bone. Below the elbow and below the knee there are two bones, some of the vessels are placed between the two bones. When you wish to stop bleeding in arm or hand injuries, tie the constrictor high on the arm, close to the shoulder, and in leg or foot injuries, tie it high on the thigh close to the groin. In these situations the vessels lie nearer to the surface than in other parts of the limbs, and are therefore more easily compressed.

2164. It will be sufficient merely to tighten a strong handkerchief around the lightly clothed limb. If this does not succeed, tie the constrictor loosely around the limb, passing a piece of broom handle or stout stick through the loop, and twist it slowly till the bleeding ceases. If this tears or bruises the skin, concentrate the pressure at one point, namely, directly upon the vessels. The course of the vessels in the limbs is easy to remember. In the upper arm they follow a line from the middle of the armpit to the middle of the bend of the elbow; and in the upper leg, from the middle of the groin to the inner side of the knee joint.

2165. First lay bare the limb; then take a small, hard object, a cork, spool, stone; wrap it in cotton or a soft handkerchief to protect the skin, and place it under the constrictor by twisting the stick. The moment bleeding ceases, discontinue the twisting. The stick can be kept in position by looping a bandage around one end of it, and tieing the two ends of the bandage on the opposite side of the limb.

2166. Keep the constrictor just tight enough to stop the bleeding, and no tighter. The pressure should be released every half hour. Should bleeding recommence, quickly replace the constrictor, but it may be laid aside, if bleeding has ceased.

Wounds

2170. To avoid introducing germs, do not wash a wound or allow your hands or the hand of the injured man to touch any part of it. If germs can be kept out, the wound will heal quickly and naturally.

2171. To protect wounds from further injury, apply a dressing, but do not put a cud of tobacco, or waste, or cobwebs, or a soiled handkerchief upon it. Go to your Emergency Box, where you will find, in clean and sterile condition, everything you will need in emergencies. A pad of gauze (called a compress) should always be laid directly upon the wound, taking care not to touch with your hands the surface next to the wound; upon this place a layer of cotton and hold in place by a bandage wound above the limb.

Burns

2175. The suffering caused by a burn is increased by exposure of the burned surface to the air. The white lead used by painters, when brushed over small burns, has been found to give immediate relief. The most convenient remedy for burns is common baking soda, a package of which is in every emergency case. For use on small burns, make the soda into a paste with water, and spread on in a thick coat. When the burn involves a large area of skin it is better to dissolve the entire package (¼ lb.) in half a gallon of water. Take enough triangular bandages from your emergency case, or clean linen from a Pullman car, or from the caboose, soak in the solution and wrap about the burned area. This dressing should be held in position with bandages, and both bandages and dressing be kept wet by frequent liberal sprinkling with the solution.

Broken Bones—Fractures

2180. A simple fracture is one in which the broken bone does not communicate with an open wound in the skin. A compound fracture is one in which the broken bone does communicate with an open wound in the skin.

2181. Ordinarily, a simple fracture need cause no alarm. It may go untended for some hours without serious risk to the patient. If the surgeon is expected to arrive within a reasonable time, make the injured person as comfortable as possible, supporting the broken limb upon pillow, folded coat or other suitable soft pad.

2182. If it should be necessary to take the patient from the scene of the accident, do not attempt to move him until the broken limb has been tightly secured by splints. The reason for this is that the ends of the bone at the break are often sharp and, if roughly handled, they will push their way through the flesh and protrude outside through the skin.

2183. Before applying splints it will greatly add to the comfort of a patient with a simple fracture if you gently draw the injured limb into its natural position, always determining the natural position by comparing the injured limb with the opposite side. But when the injury is a compound fracture, if the injured limb is doubled back under the body or otherwise bent out of line, draw gently into a straight position, but make no effort to restore its natural shape. Dress the flesh wound before putting on splints.

Eye Injuries

2190. When you get something in your eye that has fastened itself to the eyeball, do not pick at it yourself, or allow others to do so. Go to the doctor. The use of a toothpick, lead pencil or pocket knife is objectionable. Such things are usually unclean and almost certain to convey germs into the injured eye and cause inflammation.

2191. By gently turning the lid over a lead pencil you can often see the foreign body; or it may have lodged and not adhered to the eyeball. In these instances you can safely try to remove it. Around the end of a match wrap a bit of clean cotton, or the edge of a soft handkerchief. Brush this lightly over the foreign body several times. If you do not quickly dislodge it you will not be justified in continuing your efforts.

2192. A doctor should be consulted when your eye is inflamed or painful from even a slight injury.

2193. When a severe injury is received, as, for instance, laceration of the eyeball, the injured man must be taken to a surgeon immediately. Cover the eye with absorbent cotton or soft rags soaked in cold water and fasten in place with a bandage around the head. Do not make the bandage too tight, and keep the dressing wet with cold water until the patient reaches the doctor.

Electric Shock

2200. While attempting to rescue a person injured from a powerful electric current, do not touch his body if he is still in contact with the live wire or third rail, because you will receive in your own body the full force of the current.

2201. As rubber is a non-conductor, rubber gloves will give protection; or a rubber coat wrapped about the hands. But these things are not often to be had quickly, and quick action is imperative.

2202. Try to push the wire away, using a dry stick or board. If you can get hold of the coat tails or other loose portion of the clothing pull the injured man by grasping them, provided they are not wet. The current may be broken by cutting a live wire, using a hatchet with a dry wooden handle.

2203. Electric shock from powerful current is very often instantly fatal, but if it is impossible to tell in any case that life is certainly extinct, an attempt should always be made to save the life of the patient by prompt action. A doctor should be summoned with the greatest urgency, but do not waste time waiting for him, as the minutes and seconds are precious.

2204. Electric shock kills by paralyzing the breathing apparatus. The injured person has lost the power of drawing in and expelling air from his lungs. The object of your efforts is to do this for him, by putting his chest through the movements imitating breathing. The best method of practicing artificial respiration, or breathing, is as follows:

Artificial Respiration

2210. The patient is laid on the ground face down. One arm should be bent so that the forehead rests on it. The face must be turned to one side so that the air can pass into the nose and mouth. Kneeling astride the body, place the palms of your hands across the small of the patient's back with the thumbs nearly together. By bending your body forward and allowing its weight to fall on your wrists, you squeeze his chest into smaller size and expel the air from the lungs. Now release the pressure and the chest will naturally return to its normal size, and air again enter the lungs. Go through this motion about twelve to fourteen times a minute. To carry on artificial respiration is extremely laborious. The services of several persons are required to relieve one another by turns, and efforts should be kept up for at least an hour and a half, as persons apparently lifeless have been revived after long-continued labor.

Drowning—Suffocation

2215. Persons who have been rescued after more or less prolonged submersion in water, and those who have been overcome by gases as in a railroad tunnel, are precisely in the condition resulting from powerful electric shocks. They are suffocated, but the power of breathing may be only temporarily suspended. The only hope of reviving them is by artificial respiration, which should always be attempted and persisted in for two hours.

Sunstroke and Heat Exhaustion

2220. Sunstroke and heat exhaustion are caused by long-continued hard labor in the summer sun or in close, hot shops. It is of importance to be able to know which of the two conditions has been produced, because what would properly do for the aid of one would be harmful for the other.

2221. When a person receives a sunstroke, he falls unconscious. His face is red, breathing noisy, pulse weak, skin burning to the touch.

2222. When overcome by heat exhaustion, the person is simply dazed; the skin pale, cool and moist.

2223. Note the two sets of symptoms are exactly opposite.

2224. In sunstroke the heat of the body must be reduced as quickly as possible. Put the patient in a cool place and apply ice, or cloths wrung out in cold water, to his head and along his spine.

2225. In heat exhaustion keep the patient quiet and give him the assistance advised under "Shock," namely, hot tea, coffee or water, and apply bottles of hot water to his body. In either case, get the person into a doctor's care as quickly as possible.

Emergency Cases

2330. Surgeons speak of dressing material as being clean or as being dirty; there is no middle ground.

2231. The words clean, sterile, antiseptic, in the surgical sense, have the same meaning. A clean dressing is one in which the germs have been destroyed by some means, generally by exposure to intense heat, or to the action of strong chemicals, as bichloride of mercury. After being sterilized the dressing is enclosed in an airtight covering to keep the germs from it, until wanted for use. Sterile dressings are the only kind that should be applied to wounds.

2232. Examine your Emergency Case frequently to satisfy yourself that the supplies are unbroken. If any of the articles are missing, fill the deficiency at once, following the directions pasted inside of the lid.

2233. It is a good practice also to familiarize yourself with every separate article in the case, and the use it may be put to.

Splints

2240. The commonest form of splint consists of two thin, flat boards between which the injured part is securely fastened. But as railroad accidents often happen in out-of-the-way places, where choice of materials cannot be had, it will be necessary to use anything that can be made to answer the purpose of splints. Umbrellas have been used, and canes, barrel staves, fence pickets, pillows, bed clothes, etc. Whatever you select must be long enough to cover the joint above and below the seat of fracture, and if wooden splints are used they must be well padded to protect the skin against chafing and bruising. If the person is lightly clad, put on the splint outside of the clothing.

Stretchers

2245. A stretcher is provided by the Company in every shop, on every baggage car and in the care of many station agents. A list of the latter is printed in the time-tables.

2246. When it is necessary to move a person from the place of accident to a hospital or to his home, or elsewhere, and a Company stretcher cannot be produced, one can be constructed for the occasion in the following manner:

2247. The sleeves of two coats are turned wrong side out and the coats are spread on the ground with their lower edges touching. A pole is then passed through the sleeves on each side. The coats are then buttoned up with the buttonside turned down. A piece of wood should then be placed across the poles as a head rest.

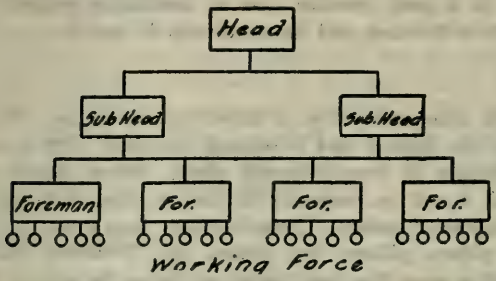
2248. The blanket stretcher is made as follows: Two strong poles should be cut to the proper length; narrow fence rails, limbs of trees, or small saplings will answer. A blanket is then placed on the ground and the poles rolled from each side in the edges of the blanket until the portion remaining unrolled is of sufficient width for a stretcher bed. This stretcher may be made more secure by wrapping cords about the portion of the blanket surrounding the poles, and the cords passed through holes made in the blanket near the poles. Two sticks or pieces of board may be fastened at either end to hold the stretcher ends apart. Many other things, easily procured, may be used for stretchers in case of necessity. Such things as doors, window shutters, boards, mats, etc.

[1]THE SCIENCE OF ORGANIZATION

Up to the present, Organization has developed as an art rather than a science and has brought out two general types, viz., the *Line* Type and the *Staff* Type.

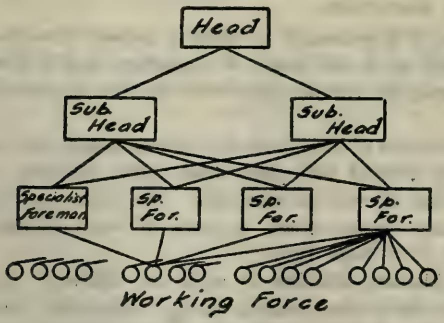
Line Type is exemplified in the army, in which there is a direct connection from the head through each subordinate to the next lower until the worker, if we may so call him, is reached.

Line Type



Staff Type is exemplified in manufacturing concerns, where there are specialists who may direct the worker in any part of his work that may be of a nature to be covered by the specialist's knowledge or authority.

Staff Type



Nearly all organizations are combinations or modifications of these two types.

In the Organization of the Engineering forces of a railroad the types work out into what is known as Departmental and Divisional Organizations, which are modified Line Types, in the manner shown in the diagrams on the following pages.

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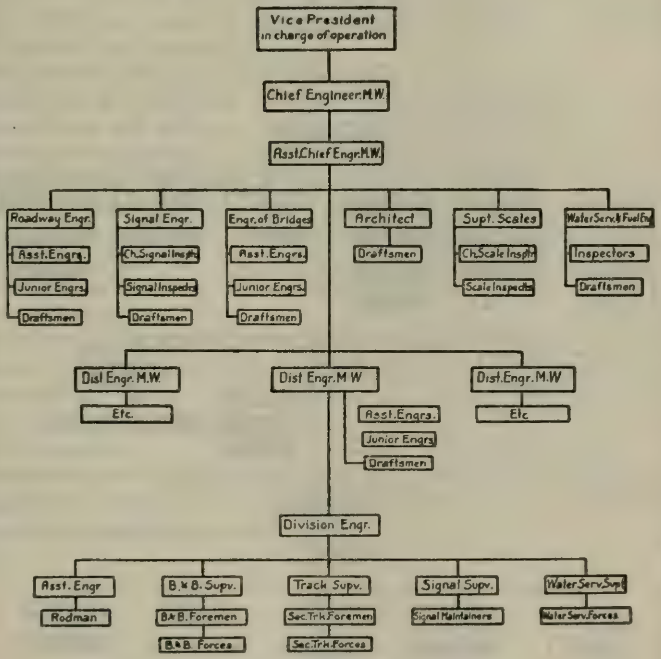
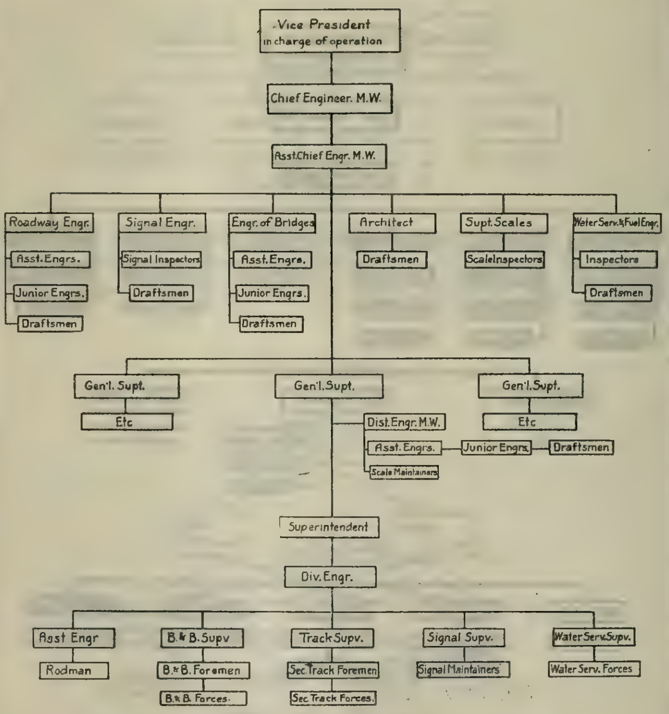
[1]Adopted Vol. 22, 1921, pp. 838, 1082.

MAINTENANCE OF WAY ORGANIZATION
(DEPARTMENTAL)



MAINTENANCE OF WAY ORGANIZATION
(DIVISIONAL)



Fundamentals of Organization

1. An organization must have its object clearly defined.
2. In its simplest form organization consists of Head and Working Force.
3. Subdivisions, combinations, extensions and modifications of this form may be made to any extent and may be most readily shown and understood by means of charts.
4. The head or Executive must
    - (a) Understand his objective.
    - (b) Plan and direct all activities.
    - (c) Select and educate working force.
    - (d) Receive results.
5. Executive must have complete authority over working force.
6. Executive may subdivide or delegate his authority, in which case each subhead must know exactly his duties and responsibilities and there must be an invariable sequence without any conflict in, nor division of, authority and responsibility.
7. There must be harmony in all relations of different subheads.
8. There must be interchange of ideas and information between all types of executives and with the rank and file, as far as possible.
9. Working force consists of equipment, tools and men, and the economic relation between these must be balanced.
10. Correct discipline is an essential feature of organization.
11. Compensation must follow the human effort in just proportion.
12. Not only physical force is available in any human organization but proper results from 10, 11 and 4c should develop in such a body an *esprit de corps*.
13. Co-ordination and correlation of work as to time, place and materials must not only be planned by executive, but he must know that it is accomplished.
14. Subheads in the smaller spheres must apply all principles used by the higher executives.
15. Standardization of methods and means must be intelligently applied.
16. Organization charts give the simplest and most readily comprehended means of expressing the system in use.

COMMITTEE XIII

WATER SERVICE AND SANITATION

[1]DEFINITIONS

Aeration.—A process of bringing water into intimate contact with air in order to introduce oxygen for the oxidation of iron or organic matter, and for washing out gases and odors.

This is usually accomplished by spraying the water through the air in fine jets.

Air Chamber.—A closed chamber used on the discharge or suction end of a pump for the purpose of promoting a uniform flow of water and to equalize stresses upon the pump.

Air Compressor.—A machine for compressing air from one pressure, usually atmospheric pressure, to a higher pressure for use as a motive force in mechanical operations.

It is used extensively for raising water from wells by means of air lift.

Air Lift.—An installation for introducing air into the column of water in a well, thereby causing it to rise.

The air is forced to the bottom of an air pipe where it is liberated either from an open pipe or through a foot piece. The air mixing with the water imparts a buoyancy to it which causes it to rise to the surface.

Algæ.—Flowerless plants of simple cellular structure without roots, stems or leaves.

They live entirely submerged in water; those common to fresh water are chiefly green, yellow and blue. Brown algae are common to both fresh and salt water.

Alkali Water.—A term commonly used to designate water containing in solution any compound of sodium or potassium in appreciable amounts.

Boiler.—A closed vessel in which water is evaporated into steam, by the application of heat.

Boiler, Locomotive Type.—A cylindrical shell and rectangular firebox surrounded by water.

The flames and heated gases of combustion, after heating the walls and crown sheet of the firebox, pass through tubes to the front end of the boiler where they escape through the stack.

Boiler, Return Tubular.—A closed cylindrical shell having a number of tubes running lengthwise through the shell below the water line, and through which the flames and heated gases of combustion pass to the stack.

Boiler, Vertical.—A closed cylindrical shell with the lower head or flue sheet placed part way up from the bottom of the boiler; this lower head, being smaller than the outside diameter of the boiler, permits of a water space between the inner and outer shell, forming the firebox.

Tubes extending from the firebox to the upper head carry the flames and gases of combustion to the stack.

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[1] Adopted, Vol. 27, 1926, pp. 179, 1300.

Boiler Compound.—A combination of chemicals applied direct to boilers or to the water in tenders of locomotives for the purpose of preventing scaling, corrosion and foaming.

Compounds are usually termed anti-scaling, anti-corrosive and anti-foaming.

Blowoff.—The act of letting out water from a boiler to carry off sediment, or to reduce the concentration of foaming salts.

Blowoff, Pipe Line.—A tee and valve located at a low point in a pipe line for the purpose of removing sediment and wasting the water when repairs are necessary.

The necessity for a blowoff depends upon the character of the water and the service of the pipe line.

Caulk.—The process of driving yarn or jute into the bell of cast iron pipe and caulking the lead tight into the joint after pouring.

Chime.—The rim around the base of the tub of a wooden water tank, formed by the ends of the staves projecting below the bottom of the floor.

Coagulation.—The process of gathering into flocs or groups, particles of finely divided suspended matter by adding coagulent to the water.

Coagulation serves a double purpose as it not only forms groups or flocs of particles that are not readily removed by subsidence or filtration, but it also forms a honeycombed layer on the filter sand which allows the water to pass and at the same time retains bacteria and suspended matter.

Continuous Plant (Water Treatment).—A plant so designed that the untreated water may be pumped to it without interruption and where the volume of the chambers through which it passes before flowing to storage is sufficient for complete reaction and precipitation.

Control Panel.—A panel usually of slate or marble, containing fuses, switches, meters, gages and other equipment, for the control of electrical machinery.

Corrosion.—The eating away of the surface of metal by chemical action, either regularly and slowly as by rusting in air, or irregularly and rapidly as by pitting and grooving in the interior of boilers.

Croze.—The cross groove cut in the staves of a wooden tank in which the edge of the floor or bottom plank are inserted.

Dam.—An artificial obstruction such as a bank of earth, a frame of wood or a wall of masonry or of concrete thrown across a valley or waterway to impound a body of water.

Drop.—The difference between the static head and the pumping head of water in a well.

Dry Steam.—Steam which contains no moisture. It may be either saturated or superheated.

Electrolysis.—The process whereby an electric current passing from an electrode to an electrolyte or vice-versa causes chemical changes to take place in the electrolyte. Electrolysis also includes any chemical changes at the surface of an electrode resulting from the chemical changes in the electrolyte.

Electrolysis from stray currents is very destructive to underground water lines and other structures in the path of the currents.

Engine, Two Cycle.—An internal combustion engine receiving a power impulse at each revolution.

ENGINE, FOUR CYCLE.—An internal combustion engine receiving a power impulse at each second revolution.

ENGINE, GAS.—An internal combustion engine using natural or manufactured gas as fuel.

ENGINE, GASOLINE.—An internal combustion engine using gasoline, naphtha or other volatile petroleum products as fuel.

ENGINE, INTERNAL COMBUSTION.—A prime mover in which the power is derived from the explosive force of the fuel compressed and ignited in a cylinder and acting directly against the piston.

ENGINE, OIL.—An internal combustion engine which is started and operated on a non-volatile oil of medium low Baume degrees, the fuel being ignited from a surface heated by previous combustion of the fuel.

EVAPORATION.—The process by which water is changed from the liquid to the gaseous state.

FILTRATION.—A mechanical process for removing suspended matter or bacteria from water by passing through sand or other close-grained medium.

FLOAT SWITCH.—A switch designed to regulate the height of water in a tank by controlling the operation of electrical pumps, the switch being opened and closed by a float.

FOAMING.—The term applied to the action of a boiler when the steam bubbles up over the surface of the water to such extent that the steam space and dome are filled, and syphoning action is started which causes water to be carried over with the steam into the engine cylinders.

FROST BOX.—A box insulated for protecting pipes against freezing. Frost boxes are usually constructed of dressed and matched lumber with one or more air spaces and lined with building paper.

HARDNESS.—The quality of water due to incrusting solids held in solution.

HARDNESS, PERMANENT.—Formerly that hardness which remained in water after boiling at atmospheric pressure, but from use it now refers to non-carbonate hardness or that hardness due to sulphates and chlorides of calcium and magnesium, which results in forming hard scale.

HARDNESS, TEMPORARY.—Formerly that hardness which was removed from water by boiler at atmospheric pressure, but from use it now refers to carbonate hardness or that hardness due to calcium and magnesium carbonates, or bi-carbonates in solution.

HEAD, FRICTION.—The increased head due to friction losses through pipe lines, pumps and fittings when discharging a given quantity of water.

HEAD PUMPING.—Static head plus friction head when discharging a given quantity of water.

HEAD, STATIC.—The difference in elevation between the surface of the water at the source of supply and the elevation at any given point.

HEAD, TOTAL.—The difference in elevation between the surface of the water at the source of supply and the elevation of the water at the outlet or the surface of the water at the highest point in a tank plus friction.

Hydrant, Fire.—Of two general types, the post hydrant in which the barrel of the hydrant extends above the surface of the ground, and the depressed hydrant in which the barrel and hose connections are placed in a box or pit, the top of which is flush with the surface.

The former is commonly used, except in congested areas where it would be in the way. The valve is located at the bottom below the frost line and is operated by a valve stem extending through the barrel. A drip valve is provided for draining the barrel to prevent freezing.

Hydraulic Ram.—A machine for raising water by utilizing the momentum of water flowing by gravity through a pipe to lift a portion of the water to an elevation greater than the source of supply.

Hydraulic Grade Line.—An imaginary line joining the points to which water flowing through a pipe line under pressure will rise at various points at atmospheric pressure.

Hoop.—A metal band of round or other cross-section encircling a wooden water tank for the purpose of holding the staves in place.

Indicator, Water Tank.—Commonly a strip of wood or metal bearing foot marks and numbers, used to indicate the depth of water in a tank.

Injector.—A device for feeding water to boilers under pressure. The water is lifted from the source of supply through the creation of a vacuum and is carried into the boiler by the momentum of a jet of steam.

Intake.—That portion of a pipe or other apparatus through which water enters from the source of supply, such as the end of an intake pipe. A structure built out into a body of water for the purpose of providing a place from which the water may be pumped without interruption.

Intake Pipe.—A line of pipe conveying water by gravity from the source of supply to an intake well or sump.

Intermittent Water Treating Plant.—A plant so designed that the water is pumped alternately into two or more treating tanks and there retained until chemical reaction and precipitation are complete.

Interception.—That part of the precipitation prevented from reaching the ground.

Lead Pot.—A round iron pot in which lead is melted.

Lead pouring pots are commonly made about 6 in. to 8 in. deep, the bottom being somewhat flat with slightly rounded sides while the top has a lip spout and a wire bale with a hook at the top. Near the bottom of the pot and on the side opposite the spout is a small hook by which the pot is tilted to pour the contents. These metal pouring receptacles vary from 5 in. to 12 in. in diameter and hold from 12 lb. to 130 lb. of lead. They are used in joining water pipe with bell and spigot ends, in soldering, etc.

Lime, Hydrated.—A dry flocculent powder resulting from the hydration of quicklime.

It is used as a reagent in the treatment of boiler waters containing carbonate hardness.

Matter, Colloidal.—Matter in a state of semi-solution which must be coagulated before removal by sedimentation or filtration.

Matter, Organic.—Vegetable or animal matter occasionally encountered in waters.

Matter, Suspended.—Matter contained in water which may be removed by filtration, coagulation or sedimentation.

Meter, Current.—A device for measuring the velocity of flow in streams and channels.

Meter, Venturi.—A device consisting of two parts, a tube which is in the shape of two truncated cones joined at their smallest diameters by a short throat piece, and the recorder which registers the quantity of water passing through the tube.

Pressure chambers are located at the upstream end and at the throat, at which points the pressures are taken.

Meter, Water.—An instrument for measuring and recording automatically the flow of water through it.

Motor, Slip Ring.—A polyphase induction motor adapted for a speed variation ranging from 50 per cent to 100 per cent, as a result of which it has a relatively low starting torque.

It is used extensively for automatic pumping outfits starting under full load as well as for other power purposes.

Motor, Squirrel Cage.—A polyphase induction motor of the squirrel cage rotor type, having a nearly constant speed with a resultant high starting torque.

This type is largely used for driving machinery.

Motor, Synchronous.—So called because it runs at the same speed or in a certain ratio to the speed of the generator.

This type of motor is used principally for power factor correction.

Outlet Pipe.—The pipe through which the water is delivered from the tank to the spout.

Percolation.—The act of water descending through the earth from the ground surface.

The passage of water through a mass of porous earth, rock, sand or other material.

Pipe, Cast Iron (Sand Cast).—A pipe made of pig iron, cast in a cylindrical sand mould with a round central core.

Pipe, Cast Iron (Centrifugally Cast.)—A pipe made from pig iron cast in a revolving water-cooled mould.

Pipe, Continuous Stave.—A wood pipe built of staves milled to radial planes and correct curvatures for the interior and exterior of pipe.

The staves are assembled in a circle and banded with steel rods, the joints are staggered and the ends of the staves have a saw kerf cut across the face in which a metal tongue is inserted in order to strengthen the joint and make it water tight.

Pipe, Wood Stave.—A pipe made of matched staves milled to radial planes and correct curvature for the interior and exterior of pipe, assembled in sections from 6 to 20 feet long, and banded either with wire or flat bands.

Pipe, Riveted Steel.—Pipe made up of steel plates which are bent so that a complete circle is made from a sheet, forming one section of pipe; the ends of the sheets are lapped the required distance and riveted.

Four sheets are usually riveted together, making the lengths of pipe 28 to 30 ft. long.

Pipe, Spiral Riveted Steel.—Pipe formed by winding a strip of sheet steel into a helical shape, with one edge overlapping the other for riveting the seam.

Pipe, Wrought Iron.—Seamless or rolled and welded from wrought iron, usually in random lengths of about 20 feet with threaded ends designed to be joined by couplings with corresponding threads.

Pipe, Wrought Steel.—Seamless or rolled and welded from wrought steel, usually in random length of about 20 feet with threaded ends, designed to be joined by couplings with corresponding threads.

Pipe, Universal.—Cast iron pipe with machined hub and spigot ends, held together by two bolts passing through suitable lugs cast on the hub and spigot ends of the pipe.

Pipe Bend (or Elbow).—A short pipe bend, usually 45 or 90 degree curve, provided with either hub end, threaded or flanged joints.

Special bends are furnished with any desired degree of curvature. Ninety degree bends are also provided with a base casting designed as a support.

Pipe, Blowoff Branch.—A casting with an opening of smaller diameter than the pipe, placed at the base and at right angles with the main pipe, designed to form a connection for a blowoff valve.

Blowoff branches for large pipe lines are frequently fitted with manholes and covers.

Pipe Cap.—A casting designed to fit over the outside of the end of a pipe to close the aperture.

Where desired the cap may be tapped for small pipe connections.

Pipe Coupling.—A short length of pipe threaded on the inside, used for connecting threaded wrought pipe.

Pipe, Cross.—A branch casting provided with connections on four sides at right angles.

Connections may be for different sizes of pipe and for either hub end, threaded or flanged joints.

Pipe Joint, Bell and Spigot.—A joint used on standard cast iron pipe, formed by a bell on one end of the pipe, the other end of the pipe being straight except for a short bead.

The beaded end is inserted into the bell, leaving a space between the bell and pipe which is caulked with yarn and filled with lead which is caulked after pouring.

Pipe Joint, Flanged.—A standard flange cast or threaded to the ends of pipe; gaskets of rubber or other material are placed between the flanges which are held in place by bolts.

This was the earliest type of joint for cast iron pipe but has been largely superseded by the less expensive and more flexible bell and spigot type of joint for underground pipe.

Pipe Offset.—A casting in the form of a reverse curve, designed for the continuation of a line of pipe in a line parallel to its beginning.

Offsets are sometimes formed of two standard bends placed end to end.

Pipe Plug.—A casting designed to be placed in the end of a pipe or fitting to close the aperture.

It may be either threaded or fitted for cast iron pipe; it may also be tapped for small pipe connections.

Pipe Reducer.—A short tapering casting designed to connect two pipes of different size.

It may be fitted on either or both ends for threaded pipe or with hub and spigot or flanged ends. The taper may be produced with plain converging walls, or it may be bottle shaped with short curves making a shoulder in the middle of the casting. Reducers used in suction lines are usually eccentric with the taper on one side of the reducer only.

Pipe Sleeve.—A short casting for connecting the ends of pipe.

A term often applied to couplings for all classes of pipe but applying particularly to cast iron pipe with hub and spigot joints. It is also furnished in flanged halves bolted together, which is termed a split sleeve.

Pipe Tee.—A pipe connection used for the purpose of joining a pipe line with another pipe at right angles.

The ends of the tee may be of the same size or of different sizes.

Pipe Vise.—A vise made especially to hold metal pipes. This device is essentially a bench tool, consisting of upper and lower oppositely serrated jaws, the upper jaw being movable while the lower jaw is stationary and integral with or fastened to a metal base plate.

Pipe Y.—A pipe connection providing for two lines of pipe diverging from one line at equal angles or one for diverging and one straight line.

The angle of the branches is usually 45 degrees unless otherwise specified.

Pipe Line, Discharge.—A line of pipe through which the water is forced by the action of the pump.

Pipe Line, Drop.—The vertical line of pipe in a well through which the water is discharged.

Pipe Line, Intake.—A line of pipe conveying water by gravity from a source of supply to an intake well.

Pipe Line, Service.—A line through which water is distributed to points of actual use as distinguished from suction lines and discharge lines to tanks or reservoirs.

Pipe Line, Suction.—A line of pipe through which a pump draws its supply.

Power Head.—A machine placed over a well connected to the power unit and which, by means of the pump rods, operates the piston in the working barrel.

Priming.—The sudden evolution of steam from a heating surface which throws water in sudden, large volumes up into the steam space.

It is due either to poor design of the boiler and to its being worked beyond capacity, or to the sudden opening of the throttle. While the effect upon the locomotive is temporarily the same, priming is different from foaming and can be mechanically controlled to a large extent by proper handling of the engine.

Pump, Single Acting.—A pump in which only one end of the plunger or piston acts on the fluid column.

Pump, Double Acting.—A pump in which the plunger or piston acts upon the fluid column on both the forward and return stroke.

Pump, Simplex Double Acting.—A pump having only one piston operated inside of a cylinder, which fills at one end and discharges at the other at each stroke.

Pump, Duplex Double Acting.—A pump having two pistons operating inside of cylinders which fill at one end and discharge at the other at each stroke.

Pump, Centrifugal.—A circular casing within which revolves an impeller mounted on a shaft. The water enters the impeller at the center and passes outward between the vanes of the impeller into the surrounding casing and to the discharge pipe.

Pump, Compound.—A direct connected steam pump in which the steam is allowed to expand in two or more cylinders.

When the expansion takes place in two cylinders it is said to be compound; if the expansion takes place in three cylinders it is said to be triple expansion, etc.

Pump, Double Stroke Deep Well.—A pump that employs two separate balanced lines of pump rods and attached water pistons.

The two lines of pump rods and their respective pistons alternate with each other in such a way that the weight or load, lifted by each rod is carried only in its tension, or up stroke.

Pump, Piston.—A pump in which a finished cylinder is closely fitted with a reciprocating piston and forces a volume of water varying with the area of piston and the stroke.

Pump, Plunger.—A pump in which the reciprocating part is a plunger which enters the cylinder through packing glands and displaces a volume of water equal to the volume of the plunger entering the cylinder.

Pump, Reciprocating.—A pump in which the piston or plunger alternately draws the water in and discharges it from the cylinder.

Pump, Rotary.—A pump, the working part of which is a revolving shaft to which are secured discs or cans, which are in close contact with the walls of the enclosing chamber or shell at two or more points.

This type differs from the centrifugal pump in that the fluid is continuously scooped out of its chamber or shell and into the discharge pipe, while in the centrifugal type the velocity is imparted to the stream of liquid by means of a fan or impeller.

Pump Stage.—A term used in connection with centrifugal pumps to indicate the number of impellers, a single stage pump having one impeller, a two stage two impellers, etc.

Pump, Triplex.—A power pump consisting of three cylinders, the pistons of which are driven by connecting rods carried by a three-throw crank shaft.

Pump, Vertical Steam.—A pump driven directly by steam in which the steam pistons and pump are usually on the same rod, used chiefly in pumping from wells.

Pump Governor.—A device for regulating the pressure of water delivered by a pump by controlling the power delivered to the pump.

Pump Rods.—The line of rods which connect the piston in the working barrel with the power head.

Pump Valve, Ball.—A ball usually made of bronze or iron, although steel and hard rubber balls are also used. The valve seat or cage may be screwed in the place of a regular valve seat, the lift of the ball being regulated by a cap which screws into the top of the cage.

This type of valve is used for handling thick liquids. It is also a very efficient valve for pumps handling lime-soda ash solution.

Pump Valve, Clapper.—A clapper valve ground to its seat and hinged so that when the valve is lifted the maximum opening in the valve deck is obtained.

This type of valve is largely used for handling tar, molasses and other thick liquids.

Pump Valve, Rubber.—A flat rubber disc with a central hole for the valve stem by which the valve is guided.

The head of the stem forms a guard for the spring which assists in seating the valve after the passage of the water.

Pump Valve, Wing.—A valve with a conical seat and provided with wings, usually four in number, which guide the valve in its seat.

This type of valve is used largely in high pressure pumps operating against pressures up to 5,000 lb. and as a rule has a comparatively low lift.

Pulsometer.—A device for pumping water by steam applied direct to the water. It consists of two pear-shaped vessels in one casting, the necks of which terminate in a single chamber having two valve seats with one ball valve which oscillates between them. It also has an air chamber and suction and discharge valves.

When charged with water, steam is admitted, the pressure of which is applied to the surface of the water in one chamber, forcing it through the discharge valve into the discharge pipe. When the steam reaches the opening leading to the discharge pipe it comes in contact with the water already in the pipe and is immediately condensed, creating a vacuum in the chamber just emptied. This vacuum draws the ball valve to the seat opposite, and prevents the further admission of steam until the empty chamber is filled with water through the suction pipe by the vacuum thus created, these operations being repeated alternately.

Quicklime.—A material, the major part of which is calcium oxide, which will slake on the addition of water.

It is used as a reagent in the treatment of boiler waters containing carbonate hardness.

Reagent.—Any chemical used for the treatment of water.

Runoff.—The name applied to that part of the precipitation which is carried off from the land upon which it falls.

Saturated Steam.—Steam of the temperature due to its pressure, not superheated.

Seepage.—Water escaping through the ground.

Sludge.—The precipitate resulting from chemical treatment, coagulation or sedimentation.

Sluice Gates.—Devices similar in construction to the gate of a valve, so arranged that they may be built into the masonry of reservoirs and other structures.

They are designed for holding water against moderate heads only.

Soda Ash.—The anhydrous normal carbonate of soda.

It is used as a reagent in the treatment of boiler waters containing sulphate hardness.

Sodium Aluminate Solution.—Aluminate of soda ($Na_2Al_2O_4$) held in solution by an excess of sodium hydrate; an intermediate product in the manufacture of metallic aluminum from bauxite, obtained by digesting bauxite with steam at about 60-lb. pressure, together with lime and soda ash. After filtration the effluent is concentrated to a gravity above 1.35 which approaches saturation.

It is used as a coagulant and as an aid to the reactions involved in softening water with lime and soda.

Solids, Incrusting.—Matter in solution or suspension which forms scale upon the application of heat.

Solids, Non-Incrusting.—Matter in solution whose solubility is above that usually found in boiler water concentrations.

SPILLWAY.—A low-level passage serving a dam or reservoir through which surplus water may be discharged; usually an open ditch around the end of the dam, a gateway or a pipe in a dam opened by lifting a gate or opening a door or valve by means of machinery, sometimes automatic, lowering the stage of water and thus reducing the pressure behind the dam and preventing the water from overtopping it.

STANDPIPE.—A tank in which the bottom is located at or near the surface of the ground, the interior of the entire structure being utilized for the storage of water.

STARTING TORQUE.—The pull on an electric motor when starting.

The starting torque of a constant speed motor is twice the full load torque on full voltage. As a general rule the torque varies as the square of the applied voltage. When 50 per cent voltage is applied to the motor, half full load torque is given.

STEEL.—Purified pig iron, which unlike wrought iron has been cast while in a molten state, and in which the carbon and impurities present in the original pig iron have been reduced to such a point that the ingot cast is capable of being forged or rolled into blooms, slabs or rails.

The amount of carbon in steel is controlled in the process of manufacture and varies from 0.10 to 1.50 per cent, depending on the use to be made of the product.

STOP COCK.—An iron or brass body fitted with a brass plug ground to seat. An opening through the plug corresponds to the opening through the body.

A quarter turn of the plug opens or closes the plug.

SUCTION.—The creation of a more or less perfect vacuum in the suction chamber of the pump and suction pipe, filling them with water by atmospheric pressure.

SULPHATE OF ALUMINA.—The commercial product known as basic sulphate of alumina. It is used as a coagulant in removing suspended matter from water.

SULPHATE OF IRON.—Known as sugar of iron, the theoretical formula of which is $FeSO_4\ 7H_2O$. It is used as a coagulant and forms a coagulum of greater specific gravity than sulphate of alumina.

It is employed chiefly in the treatment of municipal water supplies in conjunction with lime.

SUPERHEAT STEAM.—Steam heated to a temperature above that due to its pressure.

SUSPENDED MATTER.—Undissolved particles of matter in water which may be removed by filtration, coagulation or sedimentation.

They may be organic, that is, vegetable or animal matter, usually in a state of decay, or inorganic, such as particles of earth, or solids thrown out of solution through chemical action.

TANK.—A basin or reservoir on an elevated structure with the bottom located at a suitable height to deliver all water held in storage at the desired head.

TANK CAPACITY.—The number of U.S. gallons of water available above the bottom capacity line of tank.

TANK SPOUT.—A movable delivery pipe so fixed to a water tank as to conduct water conveniently into the tanks of locomotive tenders.

Tank Tower.—A structure which supports an elevated tank.

The term is also generally considered as that part of any tank structure from the top of foundation to the bottom capacity line of the tank.

Tank Valve.—The valve controlling the delivery of water from the tank to the outlet pipe.

Track Pan.—A shallow trough located between the rails, from which water is taken by locomotives while in motion by means of a scoop located under the tender.

The troughs are usually from 20 to 30 inches wide by 7 inches deep and 1900 to 3000 feet long.

Transpiration.—A process of vaporization of water from the breathing pores of leaves and other vegetable surfaces.

Turbidity.—A measure of suspended matter in the water due to silt, clay, organic matter, micro-organisms, etc.

It is commonly expressed in terms of the turbidity produced by a given weight of silica.

Valve Air.—A small valve placed at the summit of pipe lines for the purpose of letting out the air automatically and preventing the pipe line from becoming air bound with a resultant increase of pressure.

Valve, Float.—A valve which controls the height of water in a tank by the action of the water raising a float.

Valve, Foot.—A combination check valve and strainer placed at the lower end of a suction line for the purpose of keeping the suction line filled with water to assist the pump in picking up the water.

Centrifugal pumps cannot be operated successfully without a foot valve where the water is below the pump as it is necessary to have the suction line and pump filled with water in starting.

Valve, Gate.—A device for controlling the openings in pipes, consisting of a body connected in the line of pipe and surmounted by a bonnet or dome generally connected to the body by flanges. The disc or gate is actuated by a threaded stem and rises into the bonnet when the gate is opened.

Water Column.—A mechanical device consisting of valve, vertical pipe and spout, through which water is controlled and delivered to a locomotive tender.

Water Hammer.—Excess pressure or other reactions due to sudden decreases in the velocity of water flowing through a pipe line, such as closing a valve quickly or the pulsations of a pump.

Water Main Cleaner.—A device consisting essentially of a series of scrapers and piloting or propelling discs, flexibly connected, and of a design that will remove debris and incrustation from pipe lines while being forced through under water pressure or pulled through by cable.

Water Stage Register.—A device for registering the water level in streams or other bodies of water.

Water Treatment.—A process whereby water containing ingredients which are chemically or mechanically injurious to boilers is rendered harmless and fit to use in steam boilers.

Water Table.—The underground water level.

Well, Artesian.—A well in which the water level is raised above the normal ground water level by subterranean pressure.

Well, Bored.—A well sunk with an earth auger. This type of well is usually limited to a depth of 40 to 50 feet.

Well, Drilled.—A term generally used to designate a well drilled in rock or other hard material by raising and dropping a drill, the drill being rotated to secure a round, straight hole.

Well, Rotary Drilled.—A well drilled through sand or other unconsolidated material by means of a drill bit with a hollow stem rotated by power, through which water is forced to assist the bit in cutting and to remove the material. The casing is rotated down in the same manner.

Well, Driven.—A well made by driving the casing without a strainer and removing the material inside, or by driving the casing with a well point and strainer, without the necessity of removing the material.

Well, Flowing.—An artesian well in which the water rises above the surface of the ground.

Well, Gravel Wall.—A well provided with a double casing from the surface to the top of the strainer. The fine sand is pumped out through a coarse screen and gravel fed into the space between the casing to replace the sand as it is removed, thus forming a gravel wall around the screen.

Well, Pumping Head.—The level of the water in a well, measured from the surface of the ground while the well is being pumped.

Well, Static Head.—The normal water level in a well, measured from the surface of the ground while the well is not being pumped.

Well Casing.—The pipe forming the wall of a drilled or driven well.

While wrought pipe is commonly used for well casing riveted steel, cast-iron and concrete pipe are also used, particularly in the larger wells.

Well Intake.—A term commonly applied to a well for collecting surface supply in an advantageous position for pumping.

Well Screen.—A device placed in a well, designed to admit water from the surrounding area and exclude sand and other substances.

It is generally a slotted or perforated pipe, sometimes wound with wire.

Weir.—A structure used to determine the flow of water from measurements of its depth on a crest or sill of known length and form.

The notch is generally rectangular or "V" shaped, although other shapes are sometimes used.

Wet Steam.—Steam containing intermingled moisture, mist or spray. It has the same temperature as dry saturated steam of the same pressure.

Windmill.—A machine consisting of an elevated wood or steel wheel which is driven by the action of the wind.

Commonly used to operate well pumps and to a limited extent for other power purposes.

Working Barrel.—The metal tube or pump cylinder, fastened to the lower end of the drop line, which contains the valves and piston.

It is used in connection with a power head for pumping from deep wells.

Wrench, Chain Pipe.—A tool designed essentially to turn metal pipe or pipe fittings which cannot be handled effectively with an ordinary wrench.

A chain pipe wrench consists of a bar with a working end terminating between a pair of pivoted V-shaped jaws equipped with lateral wedge-shaped teeth on their top and bottom surfaces and with a chain to embrace the pipe. The chain is wrapped around the pipe to hold the bar in position, while the teeth of the V-shaped jaws grip the pipe and afford a powerful leverage.

Wrench, Stillson Pipe.—A tool designed essentially to turn metal pipe or pipe fittings. The wrench is similar to a monkey wrench except that the jaws are equipped with lateral wedge-shaped teeth to afford a firm grip on the pipe.

Wrought Iron.—A commercial iron sufficiently free from carbon and other impurities to be malleable when such metal is manufactured through the reduction of iron ores, or the refining of cast iron at a temperature so low that it is obtained in a pasty condition and, therefore, mechanically mixed with a considerable amount of slag formed during the operation.

Most of the slag is removed by hammering and rolling of the balls of metal removed from the furnace. Its carbon content varies usually from 0.05 to 0.10 per cent.

Zeolite Water Softener.—A steel shell similar to a pressure sand filter, filled with a silicate material which has the power of absorbing calcium and magnesium from the water.

This material is known as an exchange silicate as the zeolite carries sodium, which is replaced by calcium and magnesium when the water comes in contact with it. When the zeolite becomes saturated with the calcium and magnesium the mineral is revived by means of common salt.

[2]GENERAL PRINCIPLES OF WATER SUPPLY SERVICE

Supply—Quantity

The supply, if possible within economical limits, should be of sufficient volume so that the total amount of water likely to be required during the average volume of business in twenty-four hours can be drawn from the source in seven hours at terminal stations and in four hours at intermediate stations.

Supply—Quality

The quality of water should invariably be investigated when selecting a supply. Such investigations should be governed by the use for which the water is obtained. Where the supply is not required for drinking, the examination may be confined to the chemical constituents. Where drinking water is contemplated, it should be examined from a sanitary standpoint as well. Suitability of water for boiler feed depends not only upon the presence of mineral in suspension or solution that will cause sedimentation or incrustation in pipe lines and boilers, but also upon the presence of dissolved gasses or other matter, organic or mineral, that will cause or promote foaming or corrosion. The expense and practicability of treatment should be considered, where naturally suitable water is not readily available. Acid water should never be used without treatment. In general, whenever the total incrusting matter exceeds six grains per U.S. gallon, some form of treatment is desirable. However, this depends upon the quantity used, the character of the incrusting matter and the probable effect of the water when used in connection with other supplies.

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[2] Adopted, Vol. 28, 1927, pp. 210, 1290.

Supply—Source

Where water of suitable quality and in sufficient quantity can be purchased at a reasonable cost, it is recommended above all other sources.

Springs should be carefully investigated to determine their yield during all seasons of the year. The possibility or probability of their pollution and the quantity of water likely to be required in the future should be considered. If the daily flow of springs is not largely in excess of the daily quantity required, an impounding reservoir should be constructed.

Lakes, natural ponds, creeks, or rivers require special investigation in each case. The points to be considered are quantity, quality—as regards chemical impurities and the amount of sediment carried—future pollution and riparian rights.

In localities where the surface streams have intermittent flow, or where the water of these streams does not permit of treatment, and where the underground supply is insufficient or untreatable, if there is sufficient rainfall to produce an adequate runoff, resort may be had to impounding reservoirs. Wherever possible, such reservoirs should be located at an elevation sufficiently above the point of use to obtain a gravity supply. Before constructing an impounding reservoir, very careful consideration should be given to the following particulars—rainfall records, stream gaging records, average temperature and wind velocity, humidity, character of the proposed site including size, shape and nature of material, which may affect the seepage, extent of drainage area, kind of soil and nature of vegetation on the drainage area which affect the runoff.

In unproved ground, dug well construction should be preceded by test borings to reveal the strata to be penetrated. The character of the strata largely determines the size of the well and the kind of construction necessary.

Artesian wells, where obtainable, are a satisfactory source; however, their yield is liable to constant decrease and final cessation.

Deep wells that require pumping usually cost more for maintenance and operation than other sources, are generally, for that reason, undesirable but their disadvantages are often compensated by the excellence and security from pollution of the water yielded by them. Where the daily demand is relatively small, or where the water must be secured from underlying rock strata, the ordinary drilled well is satisfactory. However, when larger yields are required and may be obtained from water bearing sands or gravel, the larger gravel walled wells should be used.

Consideration should always be given to the possibility of securing a gravity supply, even though it may require pipe lines of considerable length. If the annual fixed charges on the gravity plant are less than the cost of pumping from a nearby source, the gravity plant should be adopted.

Pumping Plants

The capacity of the plant should be in accordance with the following table:

Quantity per 24 Hours, in Gallons.	Terminal Stations.		Intermediate Stations.	
	Time Pump to Run in 24 Hours.	Gallons per Minute.	Time Pump to Run in 24 Hours.	Gallons per Minute.
2,000,000	20 Hours......	1666	20 Hours......	1666
1,750,000	20 Hours......	1458	20 Hours......	1458
1,500,000	20 Hours......	1250	20 Hours......	1250
1,250,000	20 Hours......	1042	20 Hours......	1042
1,000,000	20 Hours......	833	20 Hours......	833
900,000	20 Hours......	733	20 Hours......	733
800,000	20 Hours......	666	20 Hours......	666
700,000	20 Hours......	583	20 Hours......	583
600,000	20 Hours......	500	10 Hours......	1000
500,000	7 Hours......	1189	10 Hours......	833
450,000	7 Hours......	1071	10 Hours......	750
400,000	7 Hours......	928	10 Hours......	666
350,000	7 Hours......	838	10 Hours......	583
300,000	7 Hours......	714	10 Hours......	500
250,000	7 Hours......	595	4 Hours......	1041
200,000	7 Hours......	476	4 Hours......	833
150,000	7 Hours......	357	4 Hours......	625
100,000	7 Hours......	238	4 Hours......	416
50,000	7 Hours......	119	4 Hours......	208
25,000	7 Hours......	60	4 Hours......	104

The static head should be obtained and the friction head determined in accordance with well-known formulæ or from the chart shown later, making proper allowance for the aging of the piping system.

Before selecting the type of equipment and kind of power to be used, comparative estimates of annual operating costs, including interest on the investment, depreciation, taxes and insurance, should be made and the most economical plant determined.

Steam Plants

At points where it is necessary to maintain a steam plant for other purposes, as at engine terminals, or where track pans are maintained in cold climates, steam plants will usually prove most economical.

The E.H.P. will be

$$\frac{\text{Gallons per minute} \times \text{(static head plus friction head in feet)}}{3960}.$$

The boiler selected should have the relation to E.H.P. as shown by the following table and should preferably carry not less than 100 lb. steam pressure.

Oil Engine Plants

The medium pressure oil engine, or so-called semi-Diesel type, has now been brought to a state of perfection where it is generally the most economical and practicable type of power unit for all ordinary railroad water service installations.

By reason of simplicity of operation, small floor space required, convenience in storing and handling the fuel, usually lower cost of installation, and low attendance cost, the oil engine has proven most desirable for all intermittent power service.

The crude oil distillates of 26 degrees Baumé and over are used to advantage in the semi-Diesel crude oil burning engine. To avoid trouble,

SIZE OF VERTICAL SUBMERGED FLUE AND LOCOMOTIVE TYPE BOILERS FOR RAILROAD PUMPING PLANTS FROM 1 TO 15 EFFECTIVE HP.

NOTE:—These calculations are based on boiler pressure, 100 lbs.; pump cylinder pressure, 90 lbs.; coal, 11,000 B. T. U., 25 per cent. added for contingencies; pump efficiency, 66⅔ per cent.

E. HP = Gal. per Min. × Head in Ft. ÷ 3960	I. HP at 66⅔% Pump Efficiency	Lbs. Water per Hour at 65° F. to Steam at 100 lbs., to be Evaporated at 36½ lbs. per I. HP.	Sq. Ft. Heat Surface Required for Evaporation at 2.88 Lbs. Water per Hour. per Sq. Ft. Heating Surface	Boiler HP. at 10 Sq. Ft. Heat Surface per HP per Hour. 25% Added for Contingencies		Lbs. of Coal at 11,000 B. T.U. Burned per Hour to Evaporate Water Using 2 8 lbs. per E. HP. Hour	Sq. Ft. Grate Area Required for Consumption of 13 lbs. Coal per Sq. Ft. per Hour (Given as Most Economical by Christie Tests.)	Sq. Ft. Grate Area Usually Furnished in Boilers		Lbs. of Coal of 11,000 B. T. U. Burned per Sq. Ft. Grate per Hour to Evaporate Water in Boilers as Usually Furnshd.	
				Actual	Nearest Com'l			Vertical	Loco	Vertical	Loco
1	1.5	55	19	2.8	5	28	2.15	1.76	Not Made	15.8	Not Made
2	3.0	110	38	4.8	5	56	4.32	1.76		31.8	
3	4.5	164	57	7.2	8	84	6.47	3.14		26.7	
4	6.0	219	76	9.5	10	112	8.52	3.14		35.6	
5	7.5	274	95	12.0	12	140	10.80	3.14		44.5	
6	9.0	329	114	14.0	15	168	12.90	4.90	6.3	34.2	26.6
7	10.5	384	134	16.8	20	196	15.00	7.10	9.2	27.6	21.3
8	12.0	438	152	19.0	20	224	17.20	7.10	9.2	31.5	24.3
9	13.5	492	170	21.3	25	252	19.40	7.10	9.2	35.4	27.4
10	15.0	548	188	23.5	25	280	21.60	7.10	9.2	39.5	30.5
11	16.5	603	208	26.1	30	308	23.70	9.60	12.2	32.0	25.2
12	18.0	654	227	28.4	30	336	25.80	9.60	12.2	34.8	27.5
13	19.5	713	247	30.8	35	364	27.00	9.60	12.2	37.9	29.8
14	21.0	768	265	33.2	35	392	30.00	9.60	12.2	40.8	32.1
15	22.5	822	285	35.6	40	420	32.30	9.60	12.2	43.7	34.3

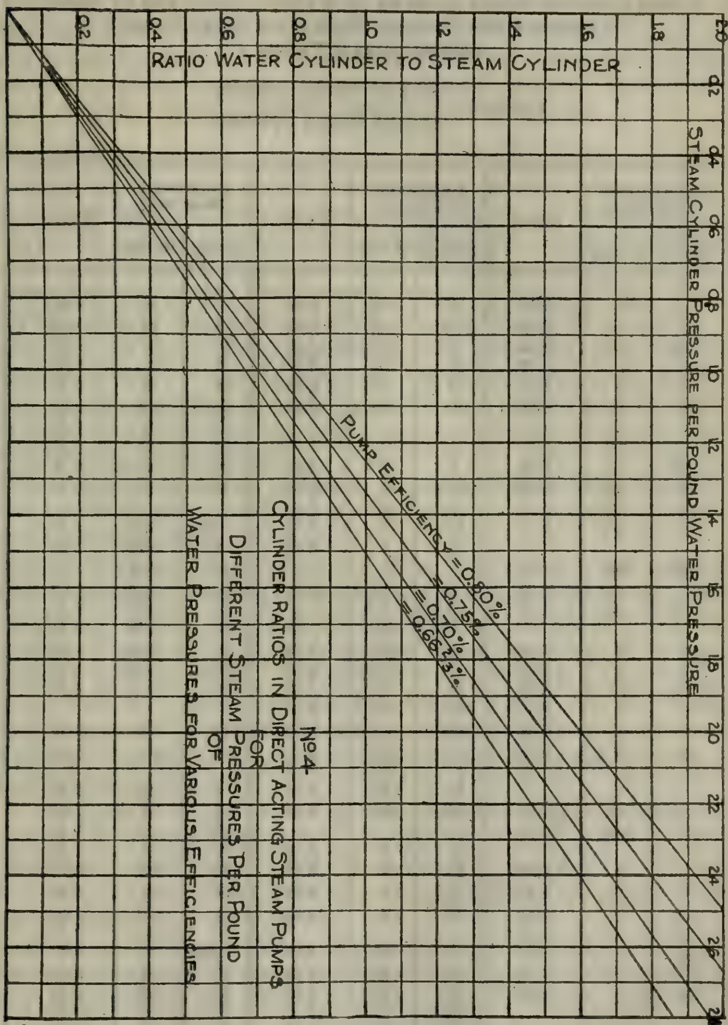
Ratio Water Cylinder to Steam Cylinder
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Steam Cylinder Pressure per Pound Water Pressure
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
Pump Efficiency = 0.80%
= 0.75%
= 0.70%
= 0.66⅔%
No 4
Cylinder Ratios in Direct Acting Steam Pumps
for
Different Steam Pressures per Pound
of
Water Pressures for Various Efficiencies

Fig. 1

TABLE 1

TABLE SHOWING RATIO OF AREA OF WATER CYLINDERS TO STEAM CYLINDERS FOR VARIOUS STANDARD SIZES DIRECT ACTING STEAM PUMPS

$$\text{Ratio} = \frac{\text{Area of Water Cylinder}}{\text{Area of Steam Cylinder}}$$

DIAMETER CYLINDERS		RATIO	DIAMETER CYLINDERS		RATIO	DIAMETER CYLINDERS		RATIO
Steam	Water		Steam	Water		Steam	Water	
6	5	0.69	6	7½	1.56	7	10	2.04
7	5	0.51	7½	7½	1.00	8	10	1.56
7½	5	0.44	8	7½	0.88	10	10	1.00
8	5	0.39	12	7½	0.39	12	10	0.69
9	5	0.31	14	7½	0.29	14	10	0.51
10	5	0.25	16	7½	0.22	16	10	0.39
						17	10	0.35
5	5½	1.21	6	8	1.78	18	10	0.31
5½	5½	1.00	8	8	1.00	20	10	0.25
6	5½	0.84	10	8	0.64	22	10	0.21
10	5½	0.30	12	8	0.44			
12	5½	0.21	14	8	0.33	7½	10¼	1.87
			16	8	0.25	9	10¼	1.30
5¼	5¾	1.20				10	10¼	1.05
6	5¾	0.92	6	8½	2.01	12	10¼	0.73
7½	5¾	0.59	7	8½	1.48	14	10¼	0.54
			7½	8½	1.28	16	10¼	0.41
6	6	1.00	8	8½	1.13	17	10¼	0.36
7	6	0.73	9	8½	0.89	18½	10¼	0.31
7½	6	0.64	10	8½	0.72	20	10¼	0.26
8	6	0.56	12	8½	0.50			
9	6	0.44	14	8½	0.37	17	11	0.42
10	6	0.36	16	8½	0.28	20	11	0.30
12	6	0.25	17	8½	0.25			
			18	8½	0.22	8	12	2.25
5¼	6¾	1.65	18½	8½	0.21	9	12	1.78
7	6¾	0.93				10	12	1.44
			14	9	0.41	12	12	1.00
6	7	1.36	16	9	0.32	14	12	0.73
7	7	1.00	18	9	0.25	16	12	0.56
7½	7	0.87	20	9	0.20	17	12	0.50
8	7	0.77				18	12	0.44
10	7	0.49	12	9¼	0.59	18½	12	0.42
12	7	0.34	14	9¼	0.44	20	12	0.36
14	7	0.25	16	9¼	0.33	22	12	0.30
			18½	9¼	0.25	24	12	0.25
			20	9¼	0.21	26	12	0.21

oil engines should not be operated in excess of their rated horsepower. A properly designed engine of the semi-Diesel type should operate on 0.6 lb. of fuel per brake horsepower hour with a consumption of not over one gallon of cylinder oil per 400 rated HP.H. in the sizes of engines up to 25 HP. and one gallon per 800 HP.H. in the larger sizes.

All gases from petroleum oils are highly explosive when mixed with the atmosphere and are heavier than air. For this reason, great care should be used to see that there are no depressions which may collect these vapors and cause an explosion. Oil engine houses should be ventilated at the floor line and wherever possible the floor should be above the ground.

Electric Plants

The use of automatic control for electrically operated pumps has resulted in large saving in operation costs in many cases. If reliable electric current is available and at a reasonable price, it is often the part of economy to replace steam pumping plants with electrically operated pumps automatically controlled, particularly where attendants may be released. Automatic control is especially applicable when the pumping station is located at a distance from the storage tank, terminal, or point where the water is used. The automatic starter is easily and conveniently controlled from any remote point by means of a pilot or actuating device. An experienced attendant is not required for its operation and complete protection is afforded the motor in starting and stopping.

Remote control is usually by means of push button, pressure regulator or float switch. Float switches are usually used in connection with automatic starters on water tank service.

Direct Current.—When considering direct current motors and starters, the mechanical structure of the pump must be taken into consideration. For a reciprocating type of pump, a motor capable of considerable starting torque must be used and a starter which will enable that motor to develop the required starting torque. This calls for a compound wound motor, which will have the advantage of the shunt field to stabilize the speed with full load or no load. The starter should be of the time limit type in order to be positive of a proper start, even though the friction of the pistons or bearings is greater than usual.

If the pump is of the centrifugal type, which requires a very light starting torque, a shunt motor can be used and either a time limit, current or counter e.m.f. limit type of starter employed. The time limit or counter e.m.f. is best for the smaller sizes up to 10 HP., while the current limit type on the larger sizes seem advisable.

Alternating Current.—When considering alternating current similar limitations must be kept in mind. With a reciprocating type of pump the use of a slip ring motor with time limit secondary type of starter is advisable. This may not be rigidly followed, but if any other type of motor is used the question of starting torque must be very carefully considered.

If a squirrel cage motor is thrown directly across the line and has a high resistance motor, it will develop more starting torque than when running, but if the motor is of such a size that it may not be possible to throw it across the line, it will be necessary to use either an auto transformer or compensator type or a primary resistance type of starter.

When considering centrifugal pumps, a squirrel cage motor can be used with auto transformer or compensator type of starter or with the primary resistor type, because the starting torque of the pump is usually well within the limits of the starting torque of the motor, with the reduced voltage.

On any automatic starter with two wire control low voltage release is provided. Overload protection can be supplied if desired.

The control equipment should be located within plain view from the motor and as close to it as conditions will permit.

Deep Well Pumping Plants

Each type of deep well pumping equipment has its respective advantages and disadvantages over other types. To insure reliability and greatest over-all economy, individual conditions should be thoroughly considered and analyzed.

In general, the most common types of such pumping equipment are the deep-well reciprocating pump, the deep-well centrifugal or turbine pump and the air lift. The deep-well reciprocating pumps are made in (1) single-plunger, single-acting type, (2) single-plunger, double-acting type, (3) double-plunger, single-acting type, and (4) triple-plunger, single-acting type.

In considering the relative merits of the different methods of deep well pumping, consideration should be given to the following features: character of the water; capacity of source of water supply; pumpage required; pumping head; first cost of complete installation of equipment; length of useful life; reliability; flexibility; efficiency, and cost of operation.

At locations where the water to be pumped from deep wells contains an appreciable amount of sand or gritty materials, the air lift pump will give the best and the reciprocating pump the poorest service. The air lift having no working parts is not affected to any large extent by such materials in the water. The leathers and valves in reciprocating pumps quickly require renewal under such conditions. The impellers and bearings of turbine pumps are worn by the gritty material and replacements or repairs are needed at intervals. The aerating effect obtained through use of the air lift pump aids in removal of iron and other impurities in the natural water. "Back-blowing" of wells with air to increase the flow and shut off the sand is also readily accomplished with an air lift pump installation.

Where the yield of a well is relatively small and strata is moderately deep, the reciprocating pump is most desirable. The turbine pump is primarily a large capacity pump and is not suitable for low yields. If a single well will not furnish the pumpage required, and if wells are widely separated the air lift is conveniently used at each well by piping compressed air from a central compressor station. For a given diameter well, the air lift will produce the largest yield.

If the water strata is capable of delivering large volumes of water, and the depth does not exceed 150 to 200 feet, the turbine pump will most economically produce the largest volume of water. The reciprocating pump will give satisfactory service at depths up to 300-400 feet, although at these depths the weight of rods requires large power heads and the delivery is limited to relatively small amounts. The air lift is limited as to depth only by the limitations of compressor; by installing stage lifts or auxiliary starting jets, the same compressor can be used for considerably greater depths. The air lift, on account of submergence necessary, requires a well hole of greater depth than the water-bearing formation, provided yield is low. The air lift with no working parts can be installed in wells which are considerably out of plumb and in which reciprocating or turbine pumps would not give satisfactory service.

As to reliability and length of useful life, the type and fitness of the pump for the service required are large determining factors. The air lift pump with no working parts below the ground is probably the most reliable, although the compressor unit may give occasional trouble. The centrifugal or turbine type pump has fewer working parts to get out of order than the reciprocating pump. The high speed of turbine-pump shafting, however, demands careful alinement of shaft and attention to bearings. To insure reliability the pump must be of proper type to fit the conditions, must be of ample capacity, must be well designed and of stout construction.

The reciprocating pump is the most flexible over a medium range of pumping yields with the least variation in pumping efficiency. The turbine type is most suitable for conditions of head and yield. The air lift pump is flexible over a great range of heads and yields although the efficiency is altered considerably. For fire protection, the turbine-type pump is most desirable as it furnishes a large quantity of water without pulsations. The air lift pump alone cannot be used successfully for fire protection.

The reciprocating pumps, being of positive action, will yield a higher efficiency than turbine or air-lift pumps. On account of its low efficiency the air-lift pump is seldom used except under specific conditions which would make the other types of pumps unsuitable.

Under average conditions the maintenance costs of the air lift systems will be the lowest and that of the reciprocating systems the highest. Attendance costs are practically the same. Each of the three systems can be operated automatically, if desired.

Power Pumps

Triplex single-acting or duplex double-acting pumps are generally used when the suction lift permits. These pumps may be direct connected to the engine or motor by a silent chain drive, or through gears, preferably using rawhide pinions. Belt drives are generally used where the pumps are placed at a different elevation or some distance away from the power unit. A friction clutch should be used on oil engine drives, as the engine cannot be readily started under the load imposed by this class of pump.

Where the suction lift is such that the pump is inaccessible for direct or belt drive, a pitman or power head with extension rods must be used. For smaller plants the single cylinder double-acting pump with pitman makes a good unit, while for larger plants the two or three cylinder pump with powerhead is preferable.

Centrifugal Pumps

The turbine pump is adapted and used for heads greater than 150 feet. A head of 150 feet per stage is figured for most satisfactory results with this type of pump, although it is possible to operate against heads as high as 300 feet per stage by operating at a high rate of speed. This, however, is not recommended as good practice.

The volute pump is a low head pump and is adapted to all classes of pumping service for which centrifugal pumps are used. Where the total head is not in excess of 150 feet it is quite as efficient as the turbine type for low heads and has the advantage over the turbine type, that there are no diffusion vanes to become clogged up or require renewal.

SINGLE AND DOUBLE SUCTION PUMPS.—A further classification of centrifugal pumps may be made by dividing them into single and double suction pumps, depending on whether the water enters the impeller from one or both sides.

ADVANTAGES OF CENTRIFUGAL PUMPS

(1) Economy as to initial cost.

(2) Low cost of maintenance.

(3) The centrifugal pump runs with less noise than the usual pumping equipment.

(4) Centrifugal pumps may be operated successfully with inexperienced labor.

(5) Failure to open a valve or the sudden closure of valves on the discharge will not affect the pump.

(6) Less floor space is required than for other types of pumps of same capacity.

(7) Are particularly adapted for handling muddy or sandy water with the least injury to working parts.

(8) Starting valves, relief valves and air chambers on discharge line or vacuum chamber on suction line are unnecessary.

(9) Can be used in series more satisfactory than any other type of pump.

(10) Pump is non-pulsating and does not cause water hammer on line.

(11) Is particularly adapted where motor is used as power and automatic operation is desired.

DISADVANTAGES OF CENTRIFUGAL PUMPS

(1) The necessity for priming.

(2) Will not operate if a slight amount of air leaks into the suction line.

(3) Other types of pumps are capable of handling higher suction lifts more successfully.

(4) Will not operate efficiently where there is a large variation in the pumping head.

Proper Size and Stage of Pump to Be Used

In order to determine the above, the following information must be obtained:

Gallons per minute required.
Static discharge head.
Suction head.
Length and diameter of suction line.
Length and diameter of discharge line.
Number of elbows and bends in both suction and discharge lines.
Nature of fluid to be pumped, whether clear or containing much sediment and grit.
Class of power.

From the above can be determined the total net head under which the pump is to operate and this in turn will determine the size of pump and the number of stages for the unit in question.

As a general rule, it is safe to say that with heads ranging from 10 feet to 150 feet we can select a single stage pump; for heads ranging from 150 to 300 feet a two-stage pump and for heads ranging from 300 feet up, three or more stages will be necessary, depending on the size and speed of the pump.

Power to be Used

The power to be used may be:

(1) Electric motor.
(2) Internal combustion engine.
(3) Steam turbine.
(4) Steam engine.

An electric motor may be either direct connected to pump or belt drive used. A centrifugal pump direct connected to an electric motor makes an excellent pumping unit and will meet practically all pumping requirements owing to the fact that motors of practically any speed can be secured. A flexible coupling should be used in direct connecting a centrifugal pump to an electric motor. The belt drive is better suited to small centrifugal pumps than to large units.

Centrifugal pumps may be operated by squirrel cage motors instead of slip ring motors as the starting torque is not great.

INTERNAL COMBUSTION ENGINES direct connected or with belt drive are particularly adapted to operating centrifugal pumps, especially for railway water service. Considering power costs alone, this is undoubtedly the most economical power that can be used.

The STEAM TURBINE has proven a satisfactory method of operating centrifugal pumps in some cases but there are but few points where it can be used in railway water service.

The use of the STEAM TURBINE for driving centrifugal pumps in railway water service is limited.

Efficient Methods of Installation

To obtain efficient operation a special study must be made of each particular installation. Conditions under which pumping units operate vary to a considerable extent and no set rules may be laid down to fit all conditions.

A certified characteristic curve of the pump at the speed recommended by the manufacturers should be furnished and studied carefully, special attention being given the following points:

1. The unloading or non-over load feature in which the power is not increased materially should the head be reduced.
2. The efficiency at various heads.

The horizontal, split casing type with enclosed impeller is recommended where conditions are adapted to its use as it presents the most accessible form of construction for inspection and repairs.

The bearings should be of the ring oiling or ball bearing type with drip pockets connected to a drain to carry away the slight leakage that should be permitted through the stuffing boxes and glands.

A flexible coupling should be used on all direct connected units to connect the pump with the prime mover, as this type of coupling allows for slight inaccuracies in the alinement of the shafts and insures cool bearings.

A check and gate valve should be placed on the discharge line near the pump.

The pump should be placed as near to the source of supply as possible, especially when operating with a suction lift.

In order to keep the suction line full of water, a foot valve or check valve should always be installed on the end of the suction line.

Hydraulic Rams

Unless the source under consideration will afford a sufficient quantity of water at all seasons of the year to meet the requirements at the particular station, and also furnish the waste water required for the operation of the ram, and unless a suitable difference in elevation exists in the source of supply, or can be created at a reasonable expense, hydraulic rams cannot be used.

The quantity of water that must be supplied to a hydraulic ram to pump a given amount of water will vary with the ratio of the supply head to the pumping head. The following chart, Fig. 2, has been prepared to show these quantities for various deliveries expressed in gallons per minute and for various values of the ratio $\frac{hd}{H}$, where hd equals the delivery head above the waste valve of the ram and the H the supply head above the same level.

Hydraulic rams are made in commercial sizes requiring from 5 to 700 gallons of water per minute for their operation.

Probably the most important features in the installation of a ram are the size and length of the drive pipe or supply line. For efficient operation the waste valve is adjusted so that the maximum velocity in the drive is approximately $0.4\ \sqrt{hd}$. The average velocity in the drive pipe is, therefore, approximately $0.2\ \sqrt{hd}$ and the pipe size should be such as to produce this average velocity. Bends, changes in section or size and other obstructions should be avoided as far as possible and where bends are necessary it will be found more satisfactory to make a long easy bend in the pipe line than to use standard short radius fittings. If strainers are used

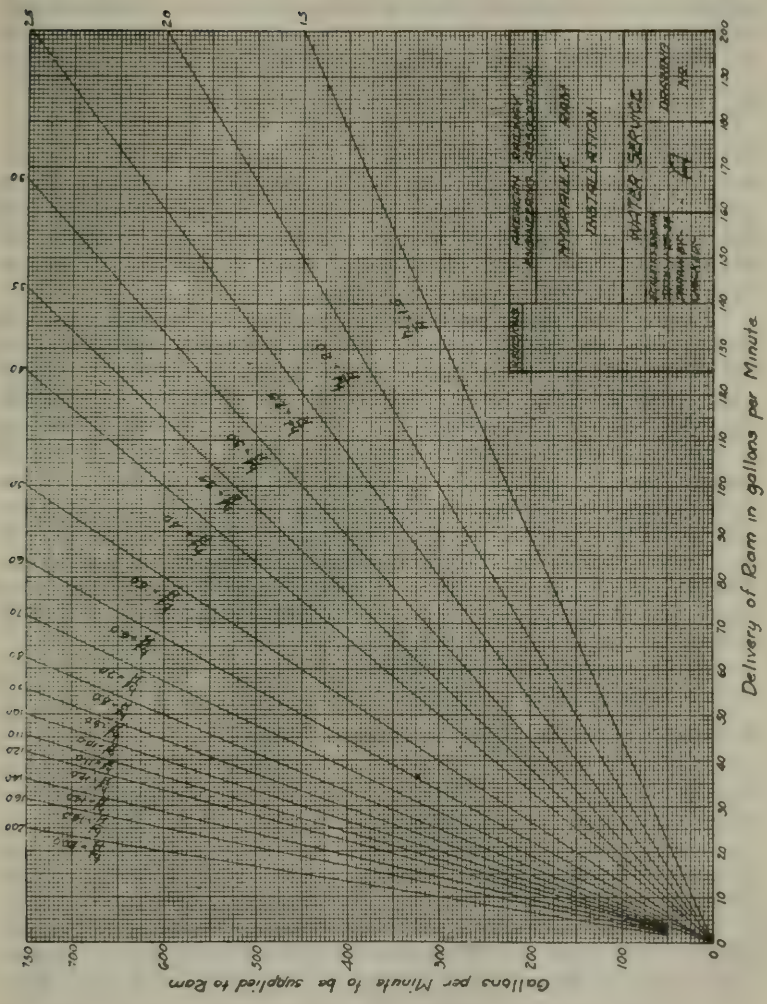
Delivery of Ram in gallons per Minute
Gallons per Minute to be supplied to Ram
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
0
100
200
300
400
500
600
700
750
25
20
15
AMERICAN RAILWAY
ENGINEERING ASSOCIATION
HYDRAULIC RAM
INSTALLATION
WATER SERVICE
DRAWING
NO.

FIG. 2

at the inlet, they should be of sufficient size and length to reduce the loss of head at entrance as much as possible.

If too long a drive pipe is installed, the required velocity in the pipe will not be created as quickly and the efficiency of the machine will be lowered. On the other hand, if the drive pipe is too short, a certain amount of the kinetic energy created will be lost by kicking out the upper end and the amount of water pumped will be lessened correspondingly. The following chart, Fig. 3, showing the relation between the factors $\frac{hd}{H}$ and $\frac{L}{hd}$ has been prepared from empirical data. It is believed that the drive pipe length as determined by the chart will produce efficient operation of the ram. It should in no case be less than 30 feet nor more than 250 feet. Where rams are installed in batteries, separate drive pipes should be laid at each ram. It will usually be found expedient to place a quick opening gate valve in the drive pipe close to the ram.

The ram itself should preferably be set in a pit at the proper drive pipe distance from the source of supply, with suitable provisions for draining the pipe of the waste water. In the event conditions are such as to prevent constructing the pit at the drive pipe distance from the source, it may be placed at some other convenient point further away, provided a standpipe or small auxiliary reservoir is constructed in the pipe line at the critical distance from the ram. In the latter case, the size of the pipe from the source to the standpipe should be increased one or two sizes and the standpipe should be of such height as to extend above the level of the water at the source of supply and be provided with a suitable air vent at its top. The ram pit or houses should be of such sizes as to afford easy access to all parts of the ram for repairs and in cold climates should be so constructed as to give ample protection against freezing.

As the ram will operate continuously, suitable overflow provisions must be made at the roadside storage tank.

Relative Economy of Different Types of Plants

Fuel oil is usually the cheapest power method for pumping water; electricity with automatic control the next cheapest, and steam and electricity with pumpers in attendance the most expensive.

The economy in the lower cost of fuel oil may be offset in some instances by decreased cost of attendance where it is practicable to decrease the number of pumpers by installing automatically operated electric pumps.

Where water of suitable quality and in sufficient quantity can be purchased at reasonable cost, a comparative estimate of the cost of pumping water using oil, steam or electric pumping plants should be made to determine the most economical source. This estimate should include interest on the investment, depreciation charges, taxes and insurance, as well as all direct charges for operation and maintenance. The supply should be purchased whenever it can be secured at a cost as low as that of pumping, using the most economical type of plant.

Pipe Lines

INTAKE LINES.—Intake lines operate under a low head and their cross-sectional area should be sufficient to convey the required quantity of water

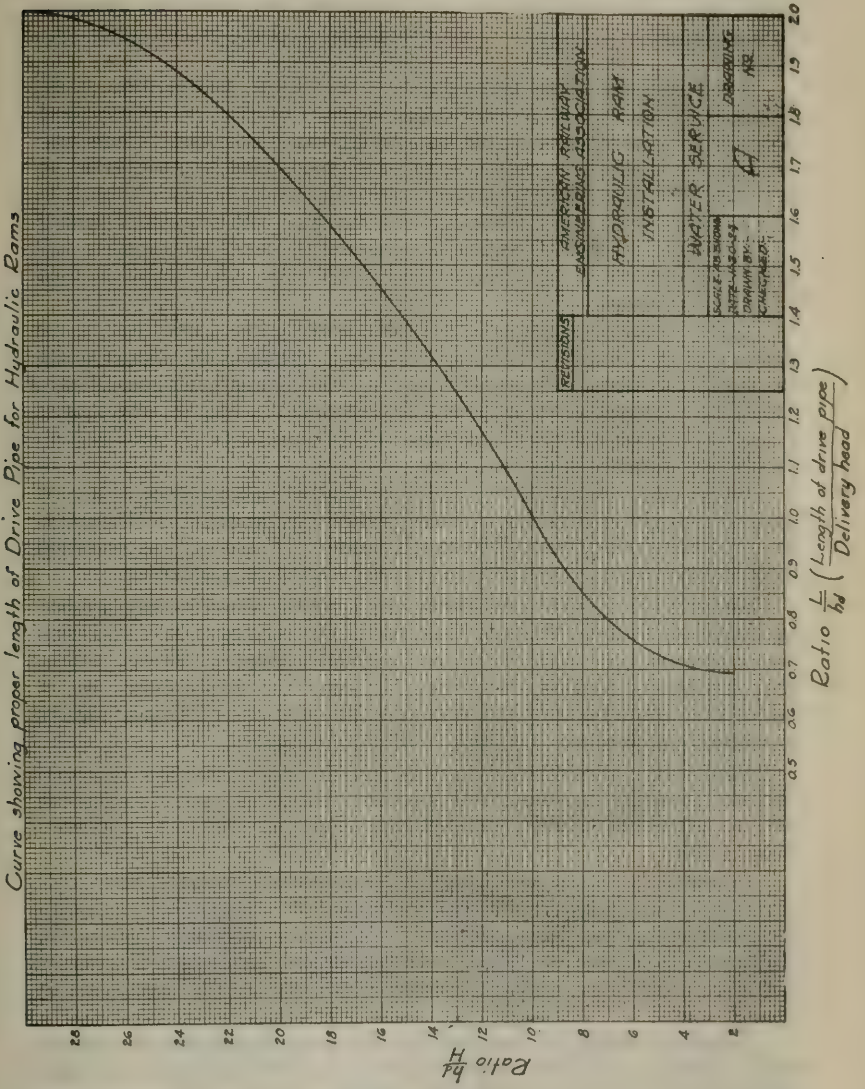
Curve showing proper length of Drive Pipe for Hydraulic Rams
Ratio $\frac{L}{h_d}$ $\left(\frac{\text{Length of drive pipe}}{\text{Delivery head}}\right)$
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
Ratio $\frac{H}{h_d}$
28
26
24
22
20
18
16
14
12
10
8
6
4
2
AMERICAN RAILWAY ENGINEERING ASSOCIATION
HYDRAULIC RAM INSTALLATION
WATER SERVICE
DRAWING NO.
SCALE-AS SHOWN
DRAWN BY
CHECKED
REVISIONS

FIG. 3

at a velocity not exceeding two feet per second. In placing intake lines in rivers, it is advisable to turn the pipe slightly down stream or to place a bend on the river end to decrease the likelihood of floating debris lodging in the pipe. Where screens are used in intakes, they should be placed in such a way as to be accessible for cleaning under high or low water conditions.

The intake line should preferably be laid to a true and uniform grade, as sags or traps in the line may collect deposits of sand or sediment and decrease the working area of the line. While almost any kind of pipe may be used for intake lines, cast iron bell and spigot pipe is generally to be preferred; but in yielding ground, or where the intake lines are subject to blows from drifting ice or debris, wrought iron pipe with screwed or flanged joints is more reliable. Where it is necessary to install long intakes following the contour of the stream or lake bed, flexible joints should be used at suitable intervals.

If the source of supply is in navigable water in the United States, the approval of the United States Army Engineer in charge of the district where the work is located should be obtained. In cases of this kind, unusual care should be exercised in locating and constructing the line so that it may resist wave action and not be damaged by passing boats. A suitable crib should be constructed at the intake end.

Intake lines constructed of sound materials and in accordance with good design require little maintenance, except where it is necessary to clean sand, ice, or debris from them. When this is necessary, the conditions requiring attention should be as accessible and as easily handled as possible.

Suction Lines.—The suction line may enter the source of supply direct or it may obtain water from an intake well. For reservoirs, lake or rivers, where there is little wave action and a small amount of floating debris, it is satisfactory to have the suction line enter the supply direct, but in bodies having severe wave action, considerable amounts of floating debris, or where ice accumulates, the intake well is recommended.

Suction lines should be as short as possible and of such size or cross-sectional area that the sum of the pipe line friction and static suction lift may be within the suction limits of the pump, and preferably not more than 15 feet.

In centrifugal pump installations it is necessary to install either a foot valve or a check valve on the bottom end of the suction line but, with reciprocating pumps, these valves are not usually necessary, unless the suction lift is excessive. Where such valves are installed, arrangements should be made for removing the debris which will usually accumulate in them.

Genuine wrought iron pipe with screwed joints is preferred for suction lines. Special care should be taken to make all joints absolutely tight and the suction line should be laid with a slight grade toward the source of supply.

Discharge Lines.—The discharge line should be laid on as straight a line and as easy a grade as cost will permit, eliminating all possible bends and fittings. Wherever possible 22½ degree bends should be used in place of 45 degree, and 45 degree bends used in place of 90 degree. The pipe line should preferably be laid as far away from present or possible future tracks as conditions permit.

A swing check valve and gate valve should be installed next to the pump and another gate valve placed near the roadside tank of discharge end of the pipe. If the pipe line is laid in hilly or rolling country, air valves to relieve air-binding should be installed at the summits, and blow-off valves to discharge sediment located in the valleys. These valves should be inspected, maintained and operated on a regular schedule and not neglected.

The economical size of the discharge line will be such that the interest on the first cost, plus depreciation, and plus the cost of pumping against the friction head will be a minimum. The cost of pumping against the friction head should be determined upon the basis of the water horsepower hours required per year to overcome the friction loss and the approximate cost of pumping estimated per water horsepower hour.

The discharge line should preferably be constructed of bell and spigot cast iron pipe, although under certain favorable conditions, other materials may prove as satisfactory and more economical. The use of lead for joints is preferred, although, under certain conditions, other materials may be used to advantage.

The cast iron pipe and fittings should conform to specifications. (Pages 902-913, inclusive.)

GRAVITY LINES.—Where favorable conditions exist, it is often desirable and economical to secure a satisfactory water supply by gravity from an impounding reservoir or other source at a sufficient elevation above the point of use. In all such cases care must be exercised in locating and laying the pipe line so that if possible no portion of it lies above the hydraulic gradient, but in case this cannot be done, special provision must be made to take care of this particular case.

[3]PIPE FOR SERVICE LINES, THREE INCHES AND UNDER IN SIZE, WITH PARTICULAR REFERENCE TO THE USE OF PREPARED JOINT CAST IRON PIPE AND COPPER AND BRASS PIPE AS SUBSTITUTES FOR STEEL AND WROUGHT IRON PIPE

(1) Service pipe materials may be divided into two general classes: The ferrous materials, of which wrought iron, wrought steel and cast iron are examples, and the non-ferrous materials represented by lead, copper and brass. The ferrous materials are cheaper, but the non-ferrous materials are more durable under similar conditions of soil and water.

(2) Cast iron pipe is extensively used for large water mains and is generally more durable than wrought iron or wrought steel. It is now commercially available in 1¼, 2 and 3 inch sizes. Its use for permanent service lines in these sizes should be considered.

(3) Extra heavy galvanized wrought iron pipe is suitable for service lines of a semi-permanent nature or for pipe sizes not available in cast iron. Galvanized steel may be considered where the installation is intended to last for a relatively short period.

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[3] Adopted, Vol. 29, pp. 185, 188.

Galvanized pipe should not be used for treated water carrying caustic soda as this will dissolve the zinc coating, making the water dangerous for drinking purposes.

(4) Black wrought iron or steel pipe for service lines are not recommended on account of the relatively lower durability and the tendency of the uncoated metal to rust and cause discolored water.

(5) Where service lines one inch, or less, in sizes are laid under pavements or in other locations where an indefinitely permanent installation is required the use of copper pipe is suggested, or brass pipe with 85 per cent copper content in preference to lead pipe, for the reason that such pipe is cheaper and stronger than lead, fully as durable, and easier to install owing to the absence of the "wiped" joint.

(6) The pre-caulked joint for cast iron pipe in 1¼, 2 and 3 inch sizes is a convenience and economy over the older method of installing the molten jointing material in the field. While pipe users have not fully accepted it, we believe their reluctance is largely due to a natural hesitation in superseding an established process until someone else has fully tried out the newer method. Small trial installations of pre-caulked cast iron pipe in 1¼, 2 and 3 inch sizes are suggested by railways interested to fully test it.

(7) The use of any form of caulked joints under railway track without encasement or other protection against vibration is not recommended.

(8) The universal cast iron joint in 2 and 3 inch sizes should be considered for use in partially settled fills or in locations subject to vibration or movement where protective measures are not provided, as this class of joint will adjust itself to considerable disturbance without leakage.

(9) Where service pipe is laid in cinders or corrosive soils or where the water has an unusual tendency to corrode or incrustate, a special study should be made to select the piping material and protective methods best suited for the conditions.

(10) Too many pipe sizes are now used for service lines. Railways should limit these sizes to a suitable minimum.

[4]SPECIFICATIONS FOR CAST IRON PIPE AND SPECIAL CASTINGS

(Adopted by the American Water Works Association May 12, 1908. Reprinted by permission.)

Description of Pipes

1. The pipes shall be made with hub and spigot joints and shall accurately conform to the dimensions given in Tables Nos. 1 and 2. They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter. They shall be at least 12 feet in length, exclusive of socket.

Pipes with thickness and weight intermediate between the classes in Table No. 2 shall be made of the same outside diameter as the next heavier class. Pipes with thickness and weight less than shown by Table No. 2 shall be made of the same outside diameter as the Class A pipe; and pipes with thickness and weight more than shown by Table No. 2 shall be made of the same outside diameter as the Class D pipe.

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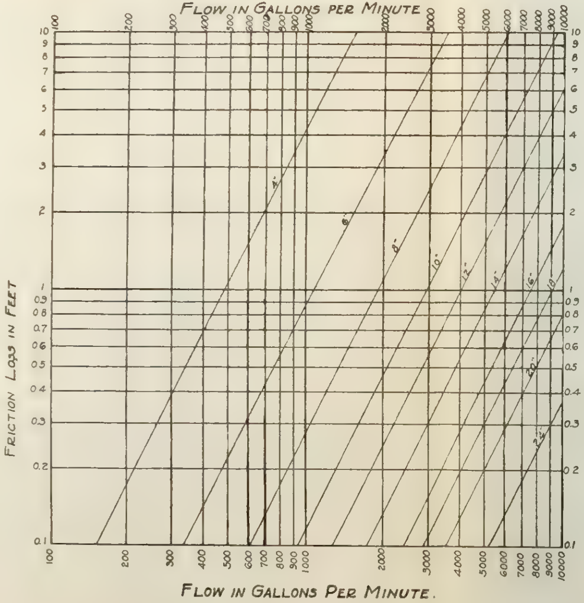
[4] Adopted, Vol. 23, 1922, pp. 514, 1113.

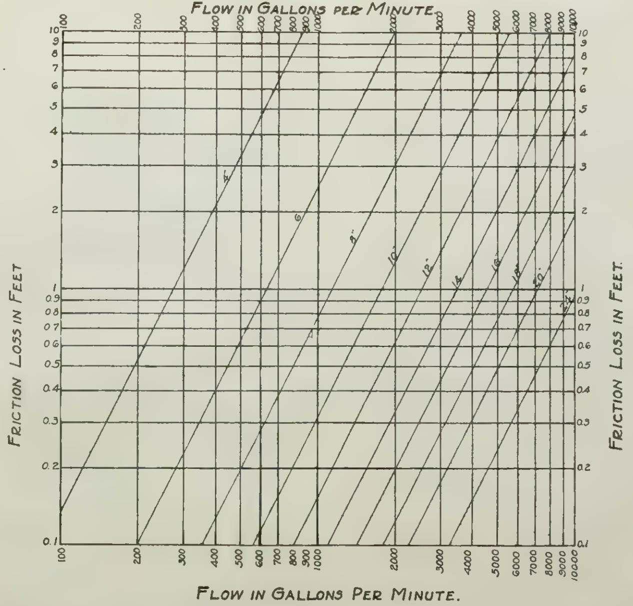
FRICTION LOSS IN CAST IRON TEES AND 90 DEGREE ELBOWS.

90 DEGREE CAST IRON ELBOWS.– (A.W.W.A. STANDARD)



CAST IRON TEES–(A.W.W.A. STANDARD).

ALSO STANDARD SCREWED AND FLANGE 90 DEGREE ELBOWS



FRICTION LOSS IN NEW CAST IRON PIPE SHOWN IN FEET PER 1000 FEET OF PIPE

BASED UPON FORMULA — $V = Cr^{0.63} S^{0.054} 0.001^{-0.04}$ AND $C = 130$

TO DETERMINE FRICTION LOSS FOR CAST IRON PIPE OF ANY AGE, MULTIPLY VALUE GIVEN ON CHART BELOW BY PROPER FACTOR SHOWN ON CHART ON THE RIGHT.

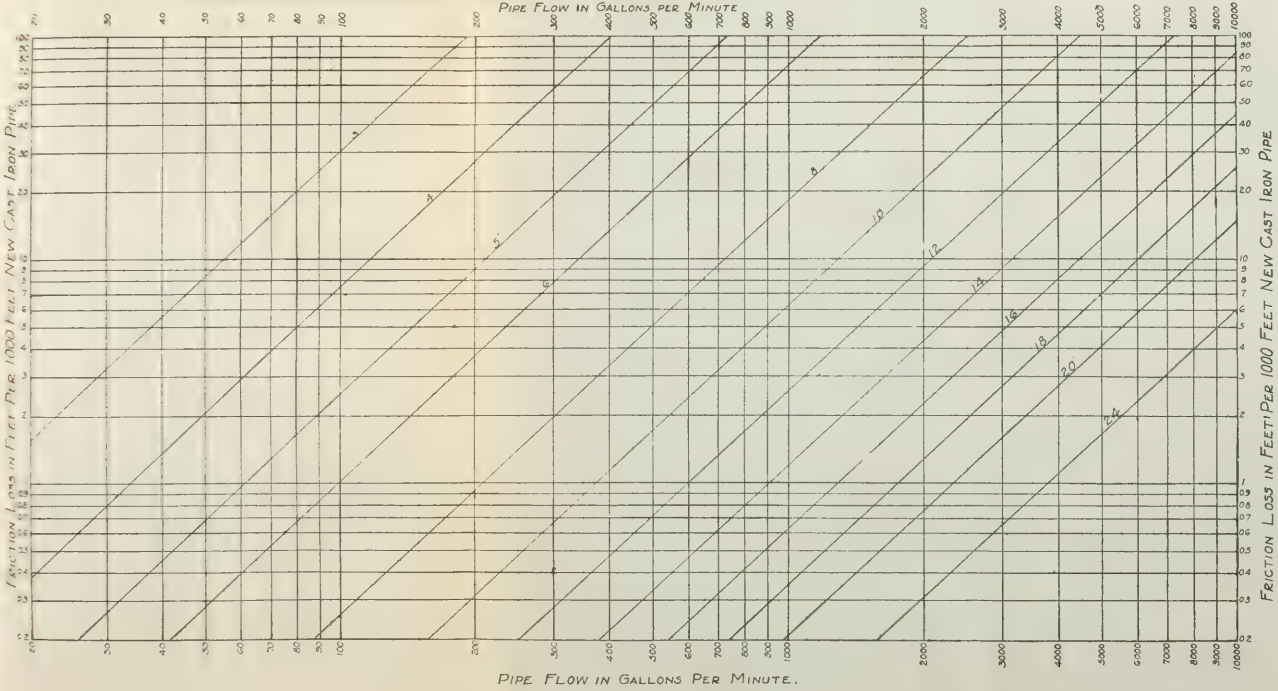
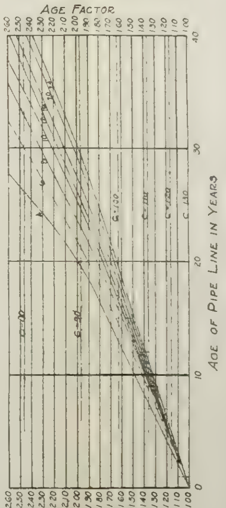


CHART TO DETERMINE FRICTION LOSS IN PIPE LINES OF VARIOUS AGES



FACTOR TO BE USED AS MULTIPLIER WITH FRICTION LOSS IN NEW PIPE TO DETERMINE LOSS FOR PIPE OF ANY AGE SHOWN

VERTICAL LINES SHOW VARIOUS VALUES OF "C" IN FORMULA.

$V = Cr^{0.63} S^{0.054} 0.001^{-0.04}$

All pipes having the same outside diameter shall have the same inside diameter at both ends. The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of about 6 inches from each of the pipes so as to obtain the required standard thickness and weight for each size and class of pipe.

For pipes of each size from 4 inches to 24 inches inclusive, there shall be two standards of outside diameter, and for pipes from 30 inches to 60 inches inclusive, there shall be four standards of outside diameter, as shown by Table No. 1.

For pipes 4 inches to 12 inches inclusive, one class of special castings shall be furnished, made from Class D pattern. Those having spigot ends shall have outside diameters of spigot ends midway between the two standards of outside diameter as shown by Table No. 1, and shall be tapered back for a distance of 6 inches.

For pipes from 14 inches to 24 inches inclusive, two classes of special castings shall be furnished; Class B special castings with Classes A and B pipe, and Class D special castings with Classes C and D pipes; the former shall have cast on the letters "AB" and the latter "CD." For pipes 30 inches to 60 inches inclusive, four classes of special castings shall be furnished, one for each class of pipe, and shall have cast on them the letter of the class to which they belong.

Allowable Variation in Diameter of Pipes and Sockets

2. Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gages, and no pipe will be received which is defective in joint-room from any cause. The diameters of the sockets and the outside diameters of the spigot ends of the pipes shall not vary from the standard dimensions by more than .06 of an inch for pipes 16 inches or less in diameter; .08 inch for 18-inch, 20-inch and 24-inch pipes; .10 inch for 30-inch, 36-inch and 42-inch pipes; .12 inch for 48-inch, and .15 inch for 54-inch and 60-inch pipes.

Allowable Variation in Thickness

3. For pipes whose standard thickness is less than 1 inch, the thickness of metal in the body of the pipe shall not be more than .08 of an inch less than the standard thickness, and for pipes whose standard thickness is 1 inch or more, the variations shall not exceed .10 of an inch, except that for spaces not exceeding 8 inches in length in any direction, variations from the standard thickness of .02 inch in excess of the allowance above given shall be permitted. For special castings of standard patterns a variation of 50 per cent greater than allowed for straight pipes shall be permitted.

Defective Spigots May Be Cut

4. Defective spigot ends on pipes 12 inches or more in diameter may be cut off in a lathe and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than 12 per cent of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than 11 feet in length, exclusive of the socket.

In case the length of a pipe differs from 12 feet, the standard weight of the pipe given in Table No. 2 shall be modified in accordance therewith.

Special Castings

5. All special castings shall be made in accordance with the cuts and the dimensions given in the tables forming a part of these specifications.

The diameters of the sockets and the external diameters of the spigot ends of the special castings shall not vary from the standard dimensions by more than .12 of an inch for castings 16 inches or less in diameter; .15 inch for 18-inch, 20-inch and 24-inch; .20 inch for 30-inch, 36-inch and 42-inch and .24 inch for 48-inch, 54-inch and 60-inch. These variations apply only to special castings made from standard patterns.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The manufacturer shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on plans and made of the best quality of mild steel, with hexagonal heads and nuts and sound, well-fitting threads.

Marking

6. Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name. When cast especially to order, each pipe larger than 4-inch may also have cast upon it figures showing the year in which it was cast and a number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below, thus:

1908 1908 1908
1 2 3

etc., also any initials, not exceeding four, which may be required by the purchaser. The letters and figures shall be cast on the outside and shall not be less than 2 inches in length and ⅛ inch in relief for pipes 8 inches in diameter and larger. For smaller sizes of pipes the letters may be 1 inch in length. The weight and the class letter shall be conspicuously painted in white on the inside of each pipe and special casting after the coating has become hard.

Allowable Percentage of Variation in Weight

7. No pipe shall be accepted the weight of which shall be less than the standard weight by more than 5 per cent for pipes 16 inches or less in diameter, and 4 per cent for pipes more than 16 inches in diameter, and no excess above the standard weight of more than the given percentage for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same number of pieces of the given size and class by more than 2 per cent.

No special casting shall be accepted the weight of which shall be less than the standard weight by more than 10 per cent for pipes 12 inches or less in diameter, and 8 per cent for larger sizes, except that curves, Y-pieces and breeches pipe may be 12 per cent below the standard weight, and no excess above the standard weight of more than the above percentages for the several sizes will be paid for. These variations apply only to castings made from the standard patterns.

Quality of Iron

8. All pipes and special castings shall be made of cast iron of good quality, and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace.

The Contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the three bars differ from those given below, a proper allowance therefor shall be made in the results of the tests.

Tests of Material

9. Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct, and in default of definite instructions the Contractor shall make and test at least one bar from each heat or run of metal. The bars when placed flatwise upon supports 24 inches apart, and loaded in the center, shall support a load of 2,000 lb. and show a deflection of not less than .30 inch before breaking; or, if preferred, tensile bars shall be made which will show a breaking point of not less than 20,000 lb. per square inch.

Casting of Pipe

10. The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16 inches or less in diameter shall be cast with the hub end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

Quality of Castings

11. The pipes and special castings shall be smooth, free from scales, lumps, blisters, sand holes and defects of every nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

Cleaning and Inspection

12. All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

Coating

13. Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar.

To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300 degrees Fahr. immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300 degrees Fahr. (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated the pipe shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.

Hydrostatic Test

14. When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure, and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressure to which the different sizes and classes of pipe shall be subjected are as follows:

	20-inch Diameter and Larger Pounds per Square Inch	*Less than 20-inch Diameter Pounds per Square Inch*
Class A pipe	150	300
Class B pipe	200	300
Class C pipe	250	300
Class D pipe	300	300

Weighing

15. The pipes and special castings shall be weighed for payment under the supervision of the engineer after the application of the coal-tar pitch varnish. If desired by the engineer, the pipes and special castings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Bids shall be submitted and a final settlement made upon the basis of a ton of 2,000 lb.

Contractor to Furnish Men and Material

16. The Contractor shall provide all tools, testing machines, materials and men necessary for the required testing, inspection and weighing at the foundry of the pipe and special castings; and should the purchaser have no inspector at the works, the Contractor shall, if required by the engineer, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the tests upon the test bars.

Power of Engineer to Inspect

17. The engineer shall be at liberty at all times to inspect the material at the foundry, and the moldings, castings and coating of the pipes and special castings. The forms, sizes, uniformity and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipe or other casting which is not in conformity with the specifications or drawings.

Inspector to Report

18. The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection.

Castings to Be Delivered Sound and Perfect

19. All pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection should not relieve the Contractor of any of his obligations in this respect and any defective pipes or other castings which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered until the final completion and adjustment of the contract; provided, however, that the Contractor shall not be held liable for pipes or special castings found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation at or any time after they have received the coating.

Definition of the Word "Engineer"

20. Wherever the word "engineer" is used it shall be understood to refer to the engineer or inspector acting for the purchaser and to his properly authorized agents, limited by the particular duties intrusted to them.

[5]SPECIFICATIONS FOR HYDRANTS AND VALVES

(Adopted by the American Water Works Association June 24, 1912. Revised June 9, 1916. Reprinted by permission.)

SPECIFICATIONS FOR HYDRANTS

(1) Size

Classification.—The size of hydrant shall be designated by the nominal diameter of the valve opening, which must be at least 4 inches for hydrants having 2½ inch hose nozzles; 5 inches for hydrants having three 2½ inch nozzles; and 6 inches for hydrants having four 2½ inch nozzles; and shall be classed as one-way, two-way, three-way or four-way, etc., according to the number of 2½ inch hose outlets for which they are designed.

Area of Water Way.—The net area of the hydrant at the smallest part, when the valve is wide open, must not be less than 120 per cent that of the valve opening.

Bell Ends or Flange Ends.—All hydrants must be fitted with bell ends to fit standard cast iron pipe, or if flanged they must be fitted with flanges of the standard dimensions corresponding to the pressure under which they are to be used; connecting pipe or flange from main to hydrant in no case to be less in diameter than the valve opening.

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[5] Adopted, Vol. 23, 1922, pp. 520, 1113.

(2) General Design

Type.—Hydrants may be of compression or gate type.

Change in Diameter.—Any change in diameter of the water passage through the hydrant must have easy curve, and all outlets must have rounded corners of good radius.

Water Hammer.—Hydrants must be so designed, particularly as regards the pitch of the thread of the operating stem, that, when properly operated a water hammer will not be caused which will give an increased pressure to exceed the working pressure, when such pressure is over 60 lb., nor increase the pressure more than 60 lb. when operated under less working pressure than 60 lb.

Broken Hydrant.—Valve when shut must remain reasonably tight when upper portion of barrel is broken off.

Friction Loss.—With a 5-foot hydrant discharging 260 gallons per minute, through each 2½-inch outlet, the total friction loss of the hydrant must not exceed 2 lb. for two-way, 3 lb. for three-way, and 4 lb. for four-way hydrants.

Strapping.—When requested, hydrants must be fitted with 2 lugs, so that the leaded joint underground can be strapped.

Flange Joints Above Ground.—When hydrant barrel is made in two sections, the upper flange connection must be at least 2 inches above the ground line.

(3) Material

Hydrant Body.—The hydrant body must be made of cast iron.

Cast Iron.—All castings shall be made from a superior quality of iron, remelted in cupola or air furnace, tough and even grain, and shall possess a tensile strength of 22,000 lb. per sq. in. The casting must be clean and perfect, without blow or sand holes, or defects of any kind. No plugging or stopping of holes will be allowed.

Specimen Bars.—Specimen bars of the metal used, each being 26 inches long, by 2 inches wide, and 1 inch thick, shall be made without charge, as often as the engineer may direct, and in default of definite instructions, the Contractor shall make and test at least one bar from each heat or run of metal. The bars when placed flatwise upon supports 24 inches apart, and loaded in the center, shall support a load of 2,200 lb., and show a deflection of not less than 0.35 inch, before breaking; or, if preferred, tensile bars shall be made which shall show a breaking point of not less than 22,000 lb. per sq. in. Bars must be cast as nearly as possible to the dimensions without finishing, but corrections may be made by the engineer for variations in width and thickness, and the corrected result must conform to the above requirements.

Wrought Iron.—All wrought iron shall be of the best quality of refined iron of a tensile strength of at least 45,000 lb. per sq. in.

Composition Metals.—All composition or other non-corrodible metals used to be of the best quality, to have a tensile strength of not less than 32,000 lb. per sq. in., with a 5 per cent reduction of area at breaking point.

(4) Hose Nipples and Valves

Hose Nipples.—Hose nipples must be of bronze or suitable non-corrodible metal, either threaded with a fine thread into the hydrants and securely pinned in place, or carefully locked and caulked in place.

Hose Threads.—Hose threads on all hydrants to be installed in any given community must of necessity be interchangeable with those already in service, but, where practicable threads should conform to the National Standard.

(5) Hydrant Seat and Gate

Seat.—The seat must be made of bronze or suitable non-corrodible metal, securely fastened in place.

Valve.—The valve must be faced with a yielding material, such as rubber or leather, except that, if of the gate type, a bronze ring may be used. The valve must be designed so that it can be easily removed for repairs without digging up the hydrant.

(6) Drip Valve

Drip.—A positively operating non-corrodible drip valve must be provided and arranged so as to properly drain the hydrant when the main valve is closed. The seat for the waste valve, which must be fastened in the hydrant securely, must be made of non-corrodible material. All other parts of the drip mechanism must be so designed as to be easily removed without digging up the hydrant.

(7) Operating Parts

Operating Threads.—The operating threads of the hydrant must be so arranged as to do away with the working of any iron or steel parts against iron or steel. Either the operating screw or the operating nut must be made of non-corrodible metal, and sufficiently strong to perform the work for which intended.

Top Nut.—The stem must terminate at the top in a nut of pentagonal shape, finished with slight taper to 1½ inches from point to flat, except for hydrants to be installed where existing hydrants have different shape or size of nut, in which case the additional hydrants must have operating nuts similar to the old one for uniformity. The nut socket in the wrench must be made without taper, so as to be reversible.

(8) Stuffing Box and Gland

Stuffing Box.—The stuffing box and gland must be of bronze or suitable non-corrodible metal, or bushed with bronze or suitable non-corrodible metal, when an iron or steel stem is used, or when an iron operating stem nut passes through the stuffing box. When packing nut is used, it must be made of bronze or suitable non-corrodible metal. The bottom of the box and end of the gland or packing nut must be slightly beveled.

Gland Bolts.—Gland bolts or stubs must be at least ½ inch in diameter. Bolts or studs may be either of bronze or suitable non-corrodible metal, iron or steel. The nuts must always be of bronze or suitable non-corrodible metal.

(9) Hydrant Top

Top.—The hydrant top must be designed so as to make the hydrant as weatherproof as possible, and thus overcome the danger from water getting in and freezing around the stem. Provisions must be made for oiling, both for lubrication and to prevent corrosion. A reasonably tight fit should be made around the stems.

Lettering.—There must be cast on top of the hydrant in characters raised ⅛ inch, an arrow at least 2½ inches long, and the word "open" in letters ½ inch high and ⅛ inch in relief, indicating direction to turn to open the hydrant.

(10) Hose Cap

Caps.—Hose caps must be provided for all outlets, and must be securely chained to the barrel with a chain constructed of material not less than ⅛ inch in diameter.

Cap Nut.—The hose cap nut must be of the same size and shape as the top or operating nut.

Washer in Cap.—When requested by the purchaser, a leather, rubber or lead washer must be provided in the hose cap, set in a groove to prevent its falling out when the cap is removed.

(11) Markings

Marking.—The hydrant must be marked with the name or particular mark of the manufacturer. All letters and figures must be cast on the hydrant barrel above the ground line.

(12) Testing

Testing.—Hydrants for pressures of 150 lb. or less, after being assembled, shall be tested by hydraulic pressure to 300 lb. per sq. in., before leaving the factory. If the working pressure is over 150 lb. per sq. in. the hydrants must be tested to twice the working pressure. The test must be made with the valve open in order to test the whole barrel for porosity, and strength of hydrant body. A second test must be made with valve shut, in order to test the strength and tightness of the valve.

(13) Directions to Open

Opening.—Hydrants must open to the left (counter clockwise) except those to be installed where existing hydrants open to the right, in which case the additional hydrants must turn the same as the old one for the sake of uniformity.

SPECIFICATIONS FOR VALVES

Castings

All iron castings shall be made from a superior quality of iron, remelted in cupola or air furnace, tough and of even grain, and shall possess a tensile strength of 22,000 lb. per sq. in. The castings must be clean and perfect, without blow or sand holes or defects of any kind. No plugging or stopping of holes will be allowed.

Test Bars

Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct, and in default of definite instructions, the Contractor shall make and test at least one bar from each heat or run of metal. The bars when placed flatwise upon supports 24 inches apart, and loaded in the center, shall support a load of 2,200 lb., and show a deflection of not less than .35 inch before breaking; or, if preferred, tensile bars shall be made which will show a breaking point of not less than 22,000 lb. per sq. in. Bars to be cast as nearly as possible to the dimensions without finishing, but corrections may be made by the engineer for variations in width and thickness, and the corrected result must conform to above requirement.

Makers' Name

Each valve shall have the makers' name cast upon it.

Wrought Iron

All wrought iron used shall be of the best quality of refined iron, of a tensile strength of at least 45,000 lb. per sq. in.

Composition Metals

All composition metals to be of the best quality, and, except the stems, to have a tensile strength of not less than 30,000 lb. per sq. in., with 5 per cent elongation in 8 diameters, and 5 per cent reduction of area at breaking point.

Face Joints

All joints shall be faced true and smooth, so as to make, with suitable gaskets, a perfectly watertight joint.

Fitting and Interchangeable Parts

The fitting of all parts must be such as make perfect joints and all parts of the valves of the same make and the same size shall be interchangeable.

Valves to open as specified by the engineer.

Bolts and Nuts

All bolts and nuts in valves to be made from the best quality of double refined wrought iron or steel, heads, nuts and threads to be standard sizes.

Kind of Valves

Valves shall be fully mounted with bronze or suitable non-corrodible metal, and be either of the double disc or made up gate type with bronze or suitable non-corrodible metal mounted wedging devices or have wedge-shaped gates with double faces and seats, designed to work equally well with pressure on either side of the gate. The gates (or discs) shall be of cast iron with bronze or suitable non-corrodible metal faces. These faces shall be machined, dovetailed and driven into corresponding machined grooves in gates (or discs) or riveted on with bronze or suitable non-corrodible metal rivets.

The seats for composition rings in body of valve shall be turned and threaded before rings are screwed in.

To Be Water-Tight

SEAT AND GATE RINGS.—Both seat rings and gate (or disc) rings shall have smooth and true faces, and make a perfectly water-tight joint.

Valves shall have hub ends suitable for laying with classes B and C American Water Works Association standard pipe. All valves 24 inches in diameter and larger shall be geared.

Bypasses.—Where bypasses are required, they shall, unless otherwise specified, be of the following sizes:

16-inch valve	3-inch bypass
18-inch and 20-inch valves	3-inch bypass
24-inch and 30-inch valves	4-inch bypass
36-inch and 42-inch valves	6-inch bypass
48-inch valve	8-inch bypass

Weight.—Valves without bypasses shall be approximately not less than the following weights for the respective sizes:

3-inch	67 lb.
4-inch	85 lb.
6-inch	180 lb.
8-inch	255 lb.
10-inch	400 lb.
12-inch	500 lb.
14-inch	780 lb.
16-inch	900 lb.
18-inch	1,290 lb.
20-inch	1,700 lb.
24-inch, geared	2,750 lb.
30-inch, geared	5,200 lb.
36-inch, geared	8,500 lb.
42-inch, geared	12,000 lb.
48-inch, geared	18,000 lb.

Valve Stems

Valve stems shall be made of solid brass or suitable non-corrodible metal, free from defects, and shall have a tensile strength of not less than 45,000 lb. per sq. in.

Threads.—Threads on stems to be square, acme or ½ V, and cut in most perfect manner, so as to work true and smooth and in perfect line throughout the lift of the valve.

Size of Stem.—Valve stems at the bottom or base of the thread shall not be less than the following sizes in diameter:

3-inch valve	44/64 inch
4-inch valve	55/64 inch
5-inch valve	55/64 inch
6-inch valve	1 inch
7-inch valve	1 inch
8-inch valve	1 inch
9-inch valve	1 8/64 inch
10-inch valve	1 8/64 inch
12-inch valve	1 12/64 inch
14-inch valve	1 12/64 inch
16-inch valve	1 28/64 inch
18-inch valve	1 28/64 inch
20-inch valve	1 48/64 inch
22-inch valve	1 48/64 inch
24-inch valve	1 62/64 inch
30-inch valve	2 12/64 inch
36-inch valve	2 32/64 inch
42-inch valve	2 48/64 inch
48-inch valve	3 32/64 inch

Wrench Nut.—The wrench nut on stem shall be .. inches square with arrow cast on showing direction which valve is to turn to open.

Painting

All iron work, after being thoroughly cleaned, to be painted throughout with asphaltum varnish, or suitable paint, or dipped in suitable coating material.

Testing

Valves must be tested for leakage and distortion as follows: On double disc or made up gate type, the body of the valve shall be drilled and tapped with a hole for pipe and a removable plug inserted, through this hole a hydraulic pressure of 300 lb. per sq. in. shall be applied; the wedge-shaped gate type by an hydraulic pressure of 300 lb. per sq. in. applied, first between one end and the gate, second between the opposite end and the gate, and third in the bonnet with gate open.

[6]WATER SERVICE ORGANIZATION

(1) The object of this department is the economical development, construction, maintenance, and operation of water stations for supplying suitable water for locomotives and other railway purposes and to secure efficiency with a minimum of change in the existing organization.

(2) The establishment of a water department organization does not necessarily mean that the division, or local forces, are materially changed, but rather that the duties pertaining to the development and operation of water facilities are placed in the hands of those trained along this particular line, relieving local and other officers of duties which may be foreign to their department. Where regular water service men are locally employed and the nucleus of an organization exists, as on many roads, the divisional organization remains practically unchanged except that duties and responsibilities are more clearly defined.

(3) The graphical chart submitted represents an organization suitable for a railroad of large mileage, and may be readily adapted to any road with modifications.

(4) The Superintendent or Engineer of Water Service shall have direct charge of chemist, inspectors and construction forces, and acts in an advisory capacity to the division forces. A monthly report of the operation of water stations shall be forwarded to the Superintendent or Engineer of Water Service, together with all other reports relating to water facilities.

City water bills, requisitions for materials used in the construction and maintenance of water facilities, as well as agreements pertaining to water supply, shall be approved by him.

(5) *Chemist*—The chemist shall report to the Superintendent or Engineer Water Service, and shall have supervision of water treatment and the analysis and examination of water. He shall periodically check the results of treatment, including the effect of treated water on the maintenance and performance of locomotive and other boilers.

(6) *Inspectors*—The inspector shall periodically inspect water stations, reporting to the Superintendent or Engineer of Water Service on proper

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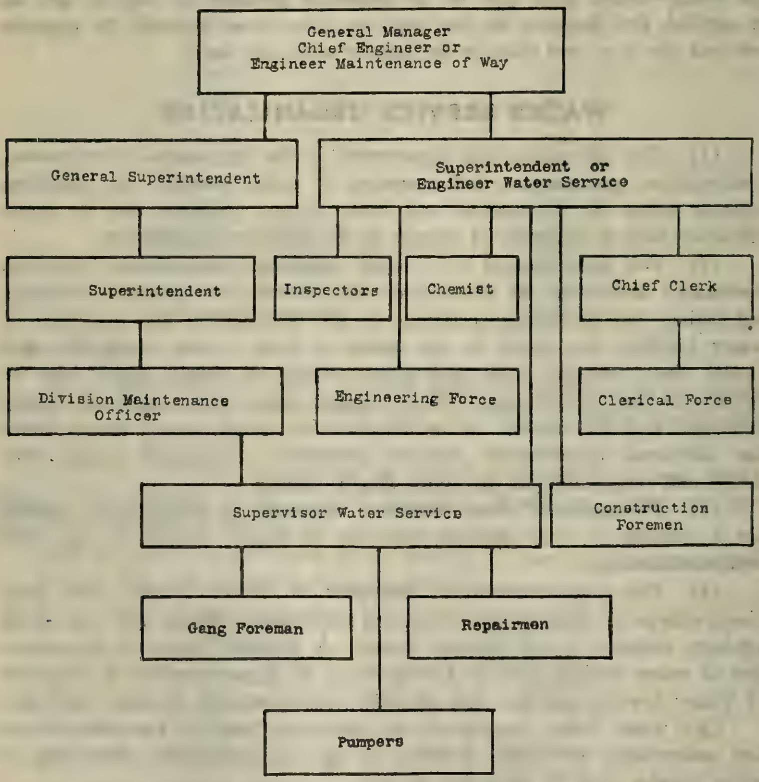
[6] Adopted, Vol. 21, 1920, pp. 57, 1348.

form the conditions in detail and the repairs and renewals required, together with the estimated cost. He will make inspections and reports on construction work, see that standards are being maintained, check estimates and recommended improvements and perform such other duties as may be assigned to him.

(7) *Supervisor Water Service*—Supervisor Water Service shall report to Division Maintenance Office, and shall have charge of gang foremen, repairmen and pumpers.

Water Service Organization



He shall be responsible for the condition, maintenance and operation of pumping machinery, tanks, fire hydrants, fire pumps, pipe lines and all other facilities for handling water on his territory.

(8) *Construction Foreman*—Construction foreman shall report to the Superintendent or Engineer of Water Service and shall have charge of construction forces and perform such other work as may be assigned to him.

PUMP HOUSES

The water supply of a railroad is of such an important facility that it is usually desirable to house the mechanical equipment required for this service in substantial buildings, generally of fireproof construction.

The size of the building will depend upon the nature of the equipment to be used. The foundations should be of concrete extending to a point at least six inches above the floor line, and a concrete floor provided with a suitable drain. For the larger and more important plants, the walls should be of brick with sufficient windows to afford adequate lighting of the interior. Smaller and less important plants may be of frame construction. In cold climates, the interior of all pump houses should be ceiled or other insulating material used to prevent freezing and possible damage to the equipment and, where conditions permit, heating facilities should also be provided. Suitable ventilators should be installed.

In southern climates, where protection against freezing is not a factor, frame buildings covered with galvanized iron will usually suffice for the small and less important plants.

All buildings housing deep well pumps should have a derrick frame extending from 20 to 35 feet above the roof of the building and over the well. This frame should rest directly on the building foundations.

[*]IMPOUNDING RESERVOIRS FOR RAILWAY PURPOSES

Introduction

The most desirable site is one from which water can be delivered by gravity or involves the least pumping head.

The impounding area should be sufficient to maintain an adequate supply throughout the longest dry period, which may extend over two consecutive years. (See Plate A.)

Conditions of Economy (Operating)

Impounding reservoirs are justified at places where the cost of water delivered does not exceed that of other equally usable dependable supply.

Selection of Site

Reservoirs should be located where the topographic and climatic conditions are most favorable. The governing factors are as follows:

Topographic:

Geographical Elevation.
Geographical Formation.
Topography.
Drainage Area.
Accessibility.
Exposure.
Size of Reservoir.
Shape.
Depth.
Water Table.
Seepage from Reservoir.

Climatic:

Temperature.
Wind.
Humidity.
Storm Path.
Precipitation.
Land Evaporation.
Transpiration.
Interception.
Runoff. { Surface.
{ Sub-Surface.
Water Evaporation.

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[*] Adopted, Vol. 21, 1920, pp. 59, 1348.

Drainage Area

This may be comparatively small, requiring from a fraction of a square mile in regions of frequent precipitation to a number of square miles in the more arid localities; the area increasing with a decrease in rainfall. The area should be favorable to a considerable surface runoff. An excessive area increases amount of silt and size of spillway.

The ratio of drainage area to spillway contour should be not less than 35 or 40, and the reservoir should have a water depth approximating 25 feet.

Water Requirements

The maximum demands for present or the near future use should be determined. The growth of traffic should be studied for a guide in forecasting the probable ultimate needs.

Land Evaporation

This is principally influenced by temperature and wind and usually varies from about one-fourth to two-thirds of the yearly rainfall.

Transpiration

This is mainly influenced by temperature and moisture and generally varies from four to ten inches during the growing season for areas having mixed vegetation, the water requirements for plants varying from three hundred to one thousand times the weight of the dry matter produced.

Interception

This is the portion of the precipitation intercepted and evaporated without reaching the ground, and is in a measure constant for each rain and probably amounts to 0.10 inch per rain, or something like 15 per cent to 40 per cent of the annual precipitation. This item is often included in the land evaporation loss.

Runoff—Surface and Sub-Surface

This is the residual precipitation after land evaporation, transpiration, interception and deep seepage losses have been deducted, and varies generally from 5 per cent to 50 per cent of the annual precipitation; often a rainfall of one-half inch is required before there is an appreciable surface runoff.

In this class of reservoirs the surface runoff is the main factor sought and is in general one-half and often greater than one-half the total runoff.

Method of Determining Runoff

All rainfall records near site and in storm path should be carefully studied and platted, likewise the daily rainfall, temperature, wind and humidity records for the period for which the calculations are made. (See Plate A.)

Runoff computations should be made for the year preceding a drought for the duration of the dry period; while the computations for the spillway should be based on the heaviest precipitations.

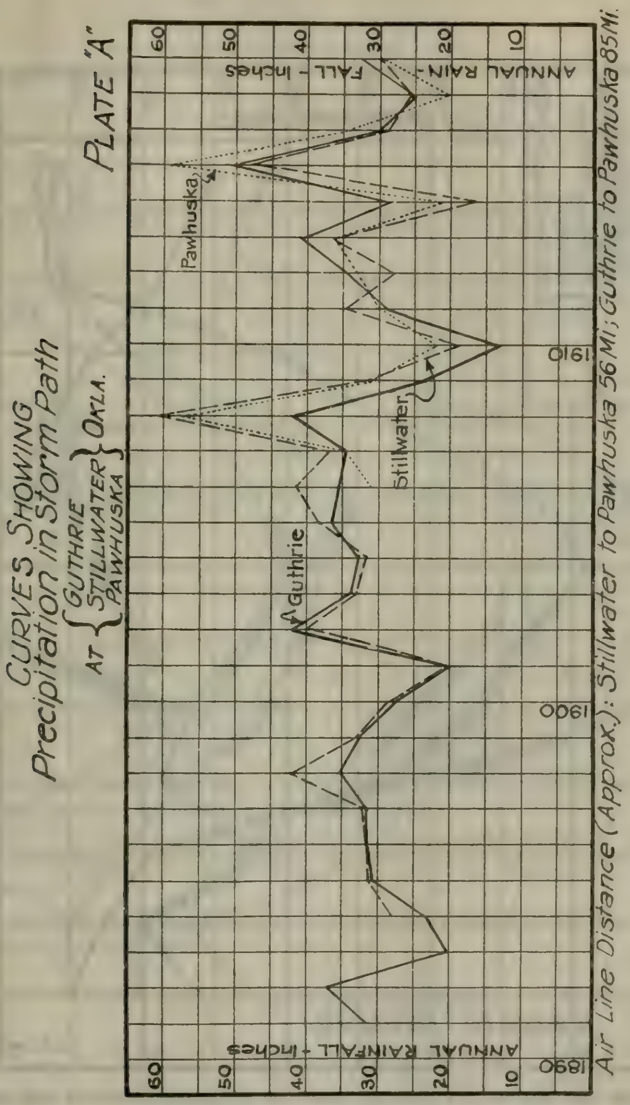

PLATE "A" INDICATES THE CLOSE RELATIONSHIP IN PRECIPITATION AT SCATTERED POINTS IN THE STORM PATH.

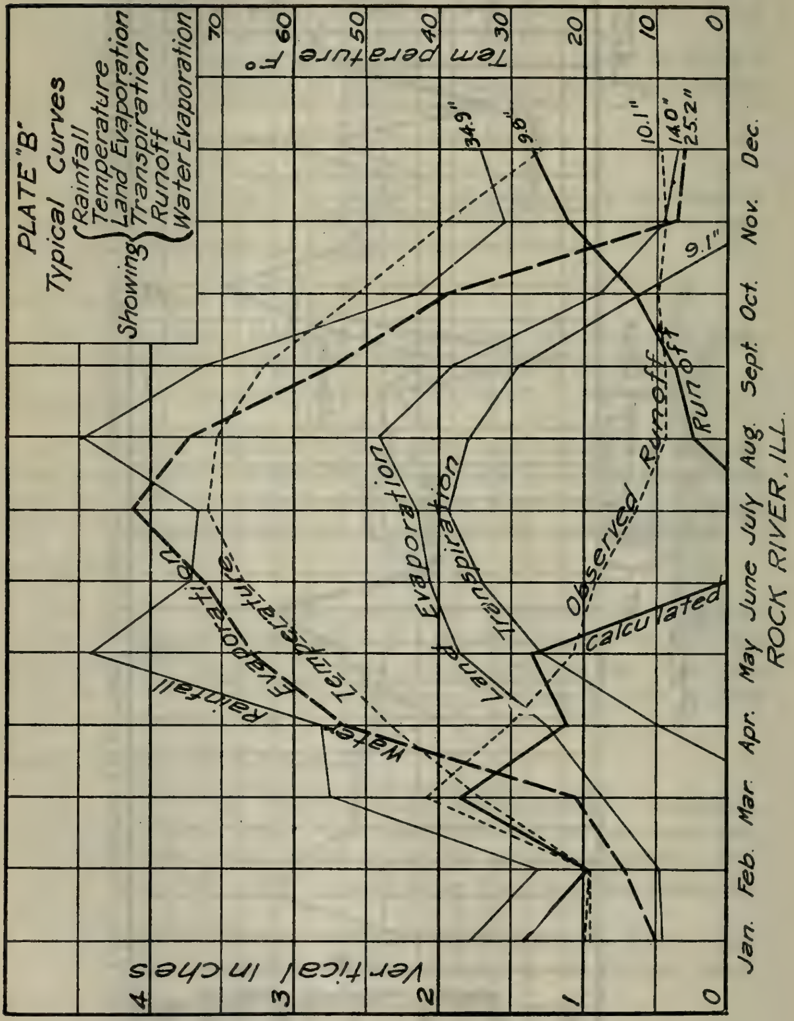

Plate "B" Shows Typical Curves for Monthly Values for the Various Factors Entering into This Subject and Apply to Northern Illinois.

The various methods can be grouped into four classes, viz.:

(1) The formula group.
(2) The percentage group.
(3) The precipitation minus loss method.
(4) The direct measurement method.

Water Evaporation

This depends chiefly on temperature, but is largely influenced by the wind and humidity. In the more arid regions evaporation from reservoir surface is the greatest loss.

[8]QUALITY OF WATER—METHOD OF TREATMENT

(1) Location of water stations and quality of water being factors affecting operating efficiency, investigation of available supplies should be made, securing as nearly as practicable favorable locations and elimination of water of inferior quality.

(2) Water usually contains scale forming matters in solution or suspension, causing trouble and expense in the operation and maintenance of locomotives.

(3) Hard water can be softened by treatment with chemicals.

(4) The hardness of water due to carbonates of lime and magnesia can be removed by use of lime, a comparatively inexpensive chemical.

(5) The hardness of water due to sulphates of lime and magnesia can be removed by use of soda ash, a more expensive chemical. The chemical reaction leaves soluble sulphates of soda, increasing the tendency to foam.

(6) The removal of sulphate is more important than removal of carbonates; the latter in absence of the former being precipitated in the boiler without forming hard scale.

(8) When use of hard water is necessary, study to determine the best method and the economical value of treating it should be made.

(9) The cost of installing a water-softening plant is determined by its capacity, prices of material and labor and locality.

(10) The cost of operating such a plant is determined by the efficiency of its apparatus and the cost and efficiency of chemicals, labor and supervision.

(11) The kind of chemicals required are determined by the quality and quantity of impurities in the water.

[9]FOAMING AND PRIMING

"Foaming" is the term applied to the action of a boiler when the steam bubbles up over the surface of the water to such extent that the steam space and dome are filled, and syphoning action is started which causes water to be carried over with the steam into the engine cylinders. Under these conditions steam loses much of its expansion properties and the effective operation of the locomotive is thereby materially impaired.

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[8] Adopted, Vol. 9, 1908, pp. 110-112, 154; Vol. 11, Part 2, 1910, pp. 1143, 1144, 1219.

[9] Adopted, Vol. 8, 1907, pp. 615, 616, 621; Vol. 16, 1915, 679, 1133; Vol. 20, 1919, pp. 280, 909.

This action is due primarily to the presence of suspended matter in the water. The suspended matter gives a mechanical strength or tenacity to the liquid in the thin films over the steam bubbles, which, rising to the surface, retain their films and collect to produce foam. It is aggravated by the concentration of alkali salts present in the natural waters or added by the process of water softening, which increases the viscosity of the surface films.

The concentration of foaming salts reaches a critical point between 100 and 200 grains per gallon, depending upon the character of the alkali salts and the amount of suspended matter in the water. To prevent foaming the concentration must be kept below this point. The best results are obtained by the systematic and frequent blowing off of the boilers, and occasional complete blowing down and washing boilers at terminals. The cost of maintaining the concentration below the critical point equals the cost of pumping, treating, and heating to boiler temperature the amount of water necessary to be blown out.

When the unavoidable concentration of foaming salts is so great that the required amount of blowing off is impractical or uneconomical, anti-foaming compounds can be used with good results.

"Priming" is the sudden evolution of steam from a heating surface which throws water in sudden, large volumes up into steam space, and is due either to poor design of the boiler and to its being worked beyond capacity, or to the sudden opening of the throttle. While the effect upon the locomotive is temporarily the same, priming is different from foaming and can be mechanically controlled to a large extent by proper handling of the engine.

[10]MINIMUM QUANTITY OF SCALING AND CORROSIVE MATTER WHICH WILL JUSTIFY TREATMENT

The minimum quantity of solids in solution that will justify treatment depends on local conditions and the composition of the solids. By applying the proper local values to the equation given below, this quantity can be determined.

The following equation gives the point where the benefits derived from treating the water will balance the cost of treating:

X = Number cwt. (100 lb.) solids removed from water per annum.

B = Money value of benefits obtained from removing 100 lb. solids; this will include:

Saving in boiler washing and repairs.

Saving in fuel.

Increased service obtained from locomotives, represented by the interest on the cost of the additional number of locomotives that would be required to perform the service rendered by locomotives using the soft water, if based on the performance prior to treating the water.

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[10] Adopted, Vol. 8, 1907, pp. 612, 613, 616, 622.

C = Cost per 100 lb. of solids removed to operate the plant, as follows:

Additional cost of labor;
Additional cost of fuel or power;
Cost of chemicals;
Cost of current repairs.

D = Cost of plant installed.
I = Interest per annum on D.
L = Estimated useful life of plant in years.
R = Estimated value of materials recovered from plant after L years.
S = Annual depreciation of plant, equivalent to a sum per year, which, if placed in a sinking fund at I rate of interest, would amount to $D—R$ in L years. (See table, page 16, Kent's Pocket Book.)

The benefits would balance the cost when

$$XB = XC + I + S. \quad \ldots\ldots (1)$$

$$X = \frac{I + S}{B - C} \quad \ldots\ldots (2)$$

The number of pounds solids removed daily to make benefits equal the cost would be $\frac{I + S}{3.65\ (B - C)}$ ......(3)

If more than this amount of solids is removed the plant will be economical.

Values for B can only be fixed for each particular case, as some of the matter held in solution is more injurious than the same weight of other matter.

[11]STANDARD METHOD OF WATER ANALYSIS AND INTERPRETATION OF RESULTS

Intention

This subject is assumed to cover only the method of analysis directly applicable to boiler waters.

The intention of standard methods for water analysis and interpretation of results is to promote uniformity and understanding of the effects caused by various constituents in boiler water supplies and enable intelligent judgment to be passed on quality of supply without full and detailed explanation as to methods used. The following information appears to include best of present practice which will, of course, be subject to change as improvements are developed.

General

The general practice for reporting railroad water analyses is in terms of grains per U.S. gallon, which is equivalent to parts per 58,341. This appears to convey a better impression of the actual condition of the water, which is the ultimate purpose of the analysis, and it is recommended that reports of water analysis in grains per gallon with supplementary advice as to pounds per thousand gallons of total incrustants, total non-incrustants, and total solids, be adopted as standard practice.

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[11] Adopted. Vol. 25, 1924, pp. 169, 1246.

Form and Combination

Although the actual determination of substances in water are usually made of the various elements or radicals direct, the customary and accepted practice for reporting results of water analysis is by hypothetical combinations of the elements. The following method is recommended for uniformity:

Silica—as found.

Iron and aluminum oxides—as found (except in special cases of acidity, where more extensive determination should be made).

Make combination of positive radical determined, to negative radicals as found, in following order of sequence:

Positive Radicals	*Negative Radicals*
Calcium	Carbonate
Magnesium	Sulphate
Sodium	Chloride
Potassium	Nitrate

Interpretation

Incrustants.—It is understood that the silica, iron and aluminum oxides, and the calcium and magnesium combinations will be classed as incrusting solids.

Non-Incrustants.—The sodium, alkali salt combinations, and organic matter will be classed as non-incrusting.

Corrosive.—All acids, iron and aluminum sulphate, calcium chloride and nitrates, magnesium sulphate (in appreciable amounts), chloride, and nitrate will be classed as corrosive salts.

METHOD OF ANALYSIS

Field Survey—or Rapid Check Tests

Field survey tests for boiler waters are generally confined to a means of approximating the total hardness or total amount of scale forming matter, and the division of this figure into the alkalinity (carbonate hardness) and the sulphate hardness, as well as an approximation of the ratio of the calcium and magnesium salts. With experience in manipulation, the following procedure can be made to give close and very satisfactory results.

Reagents

(1) Standard Calcium Chloride Solution.—Dissolve 0.5 grams of pure calcite (calcium carbonate) in a little dilute hydrochloric acid, being careful to avoid splattering. Wash down and neutralize with ammonium hydroxide to slight alkalinity, litmus paper indicator. Make up to 500 cc. with carbon dioxide free distilled water and store in glass-stoppered bottle. One cc. of this solution is equivalent to 1.0 mg. calcium carbonate.

(2) Standard Soap Solution.—Make up stock solution by shaking vigorously, approximately 100 grams of powdered castile soap or sodium oleate in one liter of 80 per cent grain alcohol or nearest obtainable equivalent denatured with methyl alcohol and allow to stand at least over night. Dilute the clear supernatant liquid with 70 per cent grain alcohol

or nearest obtainable equivalent denatured with methyl alcohol, until 1.0 cc. is equivalent to 1.0 cc. of the standard calcium chloride solution, making due and recorded allowance for a lather factor which will vary from 0.7 to 1.4 cc. with different soaps. One cc. of this solution is equivalent to 1.0 mg. calcium carbonate.

(3) N/50 Sulphuric Acid.

(4) N/50 Sodium Carbonate.

Procedure

(a) Measure 58.3 cc. of the water into an 8-ounce bottle. Add the standard soap solution 1.0 cc. at a time, shaking vigorously after each addition, until a strong permanent lather is secured, and as the end point is approached, cut the additions of soap solution to 0.5 cc. Make note of the false end point, which is the dividing line between the calcium and magnesium salts, and record. The final end point, after deducting lather factor, gives direct the total hardness as grains per gallon in terms of calcium carbonate. The difference between the false point and the total hardness gives the amount of magnesium salts, the balance being calcium salts, all as grains per gallon in terms of calcium carbonate. In determining the hardness in acid waters, they should first be rendered neutral to methyl orange by addition of N/50 sodium carbonate. If hardness test runs above 15.0, it is best to take aliquot portion and dilute to 58.3 cc. with distilled water, so that the later end point will be less than 15, multiplying the result accordingly to obtain correct hardness.

(b) Titrate 58.3 cc. of the water with N/50 sulphuric acid solution methyl orange indicator, and record as alkalinity, this point being the carbonate hardness in terms of calcium carbonate direct as grains per gallon.

In case of alkaline waters, if the total hardness is greater than the alkalinity, the difference between the two represents sulphate hardness. If the total hardness is less than the alkalinity, the difference is sodium carbonate, all of the hardness being carbonate hardness, the hardness being composed in either case of calcium or magnesium salts as determined by the false and true end points in the soap test. In case of acid waters, all hardness will be sulphate hardness.

(c) In case the water is acid to methyl orange, titrate 58.3 cc. with N/50 sodium carbonate solution and record acidity direct as grains per gallon in terms of calcium carbonate.

(d) When treated water is being tested, first titrate 58.3 cc. of the water with N/50 sulphuric acid, phenolphthalein indicator. Double the reading and report as causticity. Continue the titration with methyl orange indicator, recording the reading direct as alkalinity. Soap test is made as above noted and reported as hardness.

The difference between the hardness and alkalinity shows an overtreatment in soda ash if the alkalinity is in excess, or an undertreatment if the hardness is in excess, directly in grains per gallon in terms of calcium carbonate. Likewise, the excess of causticity over alkalinity indicates an overtreatment with lime or caustic soda, while an excess of alkalinity over causticity shows an undertreatment direct in grains per gallon in terms of calcium carbonate. In other words, this difference shows the excess or deficiency of hydrate alkalinity.

Rapid Laboratory Method

This method is recommended routine laboratory procedure where quick results are desired which will satisfactorily differentiate between constituents normally present in waters and furnish sufficient information for making ordinary analysis report, so that judgment may be made as to general effect of quality.

Reagents:

(a) Standard soap solution, 1.0 cc. equivalent to 1.0 mg. calcium carbonate.

(b) N/50 sulphuric acid.

(c) N/20 soda reagent, prepared of one-half N/20 sodium hydroxide and one-half N/20 sodium carbonate.

(d) Clear saturated lime water, prepared by shaking excess of C.P. hydrated lime with distilled water and let settle.

(e) Standard sodium chloride solution, 1.0 gram dissolved in 1,000 cc. distilled water. One cc. is equivalent to 1.0 mg. Nacl.

(f) Standard silver nitrate solution. One cc. is equivalent to 1.0 cc. standard sodium chloride solution.

Procedure

(a) Evaporate 58.3 cc. of water to dryness in weighed dish, and bake for 30 minutes at 180 degrees Centigrade. Weigh up as total solids, milligrams giving grains per gallon direct.

(b) Titrate 58.3 cc. of the water with N/50 sulphuric acid and methyl orange indicator, which gives grains per gallon of carbonate and hydrate alkalinity direct from number of cc. used, in terms of calcium carbonate.

(c) Take 116.7 cc. of water in 250 cc. Erlenmeyer flask, and boil for 15 minutes. Add predetermined amount of soda reagent from pipette, so that, as shown by soap test, there will be an excess equivalent to at least 10 grains per gallon. Boil 10 minutes additional and then pour into 200 cc. graduated flask, adding sufficient distilled water so that solution will be at mark, then cool. Filter off 100 cc. and titrate with N/50 sulphuric acid, methyl orange indicator. Along with this sample a blank should be run using the same amount of distilled water as in sample and treated with same amount of soda reagents, making up to 200 cc. after boiling. The difference between amount N/50 sulphuric acid required for neutralizing 100 cc. of blank and the sample gives the incrusting sulphates direct in terms of calcium carbonate. If the difference is negative, it shows the amount of free sodium carbonate direct as grains per gallon in terms of calcium carbonate.

(d) Take 116.7 cc. of samples in 250 cc. Erlenmeyer flask and exactly neutralize methyl orange indicator. Boil 15 minutes to expell all carbon dioxide and then add solution of saturated lime water so that, as shown by soap test, there will be an excess equivalent to at least 10 grains per gallon. Continue boiling for 15 minutes. Pour into 200 cc. graduated flask and add distilled water so that solution will be at mark when cool. Filter and titrate 100 cc. with N/50 sulphuric acid. Along with this sample a blank should be run using the same amount of distilled water as in sample and treated with the same amount of saturated lime water, making up to 200 cc. after boiling. The difference between amount of N/50 sulphuric acid required for neutralizing 100 cc. of blank and the sample gives the amount of magnesium present direct in grains per gallon in terms of calcium carbonate.

(e) In making final report compare results from No. (c) and No. (d). If No. (c) is in excess of No. (d), calculate No. (d) direct to magnesium sulphate and the difference to calcium sulphate, all of No. (b) being calcium carbonate.

If No. (c) is less than No. (d), calculate No. (c) direct to magnesium sulphate and the remainder of No. (d) to magnesium carbonate, this remainder of No. (d) to magnesium carbonate, this remainder of No. (d) being also subtracted from No. (b), the difference being calcium carbonate.

If No. (c) is negative, make proper allowance in No. (b) for the amount of sodium carbonate, calculate No. (d) to magnesium carbonate, making allowances in No. (b) and the remainder of No. (b) being calcium carbonate.

(f) Titrate 58.3 cc. sample with silver nitrate solution, potassium chromate indicator. Result gives sodium chloride direct in grains per gallon.

(g) If the silica and iron aluminum content amount to more than one grain per gallon, it may be well to separate and weigh up by the usual gravimetric methods, using 291 cc. sample and multiplying diagrams by two (2) to obtain grains per gallon. If the amount is below this, which is usually the case, same can be estimated with sufficient accuracy by colorimetric determination.

(h) The difference between No. (a) and the sum of the calculations in No. (e), No. (f) and No. (g), give the amount of non-incrusting sulphates. nitrates and organic matter. There is no necessity for separating these constituents in the ordinary boiler water analysis unless, after heating the residue in the No. (a), a black discoloration shows high organic matter which might induce foaming. The sulphate may then be determined gravimatically as barium sulphate or rapidly by the Parr Sulphotometer, and the organic matter taken as the difference.

Full and Complete Laboratory Examination

For full and complete examination of boiler waters as may be required in special cases, it is recommended that the procedure outlined in the latest edition of "Standard Methods of Water Analysis," published by the American Public Health Association, be followed. These methods were adopted as standard by that association after collaboration with other scientific societies and have been universally accepted.

[12]WATER SOFTENERS

(A) DESIGN AND INSTALLATION

(1) Study should be made to determine the best method and economical value of treating the water, controlling conditions considered.

(2) Generally, installation of softening plants should follow a plan based on the operating division. Usually the complete equipment of one division will give better results than an equal number of plants scattered over a number of divisions.

(3) Whether or not the water can be successfully treated should be determined. Water sometimes contains solids of such character, combination and quantity that the water is unfit for use after treatment.

(4) The plant should have adequate capacity. Probable increase in water consumption should be anticipated.

(5) The mechanical apparatus should be simple in construction and operation, stable in adjustment and should accurately and uniformly introduce the chemicals into the water in necessary proportion.

(B) OPERATION, MAINTENANCE AND SUPERVISION

(1) Adequate and capable supervision, preferably by a chemist or engineer experienced or skilled in water treatment, is necessary to secure the best results.

(2) As a check on the treatment and to keep it properly adjusted to changes in the quality of the untreated water, frequent analyses of the water, treated and untreated, should be made by a competent chemist.

(3) Where consumption of water is in excess of the effective capacity of the plant, the use of untreated, milky water should be avoided by the use of raw water to such an extent as to give ample time for the proper treatment of all water that passes through the softener. The exception to this rule is the case of water which is being treated for corrosive properties. Such water should not be used raw if it can be avoided.

(4) The reagents, as nearly as practicable, should be chemically pure.

(C) CAPACITY

Where the lime and soda ash treatment is used, the volume of space for reaction and precipitation should be at least from three to four times the hourly capacity of the softener, depending on temperature and analysis of the water.

In continuous softeners, the capacity of the tank reserved for treatment and sedimentation should be not less than three or four times the hourly capacity of the plant, depending on the temperature of the water, low temperature requiring the larger capacity.

The determination of the number and volume of settling tanks for intermittent softeners depends on the number of pumps or batteries of pumps necessary to handle the water; time required to fill or empty each settling tank, above the sludge line, and time necessary for reaction and precipitation.

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[12] Adopted, Vol. 8, 1907, pp. 604-607, 615, 617, 620, 621; Vol. 16, 1915, pp. 678, 1133.

RELATIVE ECONOMY

The relative economy of the different types of water softeners can be determined by comparing the total annual cost of each, exclusive of the cost of chemicals. This annual cost should be composed of:

(a) Interest on the sum of the cost of installation and value of ground space occupied;

(b) Depreciation;

(c) Current repairs;

(d) Increased cost of operating the water station due to additional labor and fuel required for the treatment.

REAGENTS

The quantity of reagents required per unit of scaling or corroding substance held in solution, given in accompanying table, is recommended as good practice.

Where the commercial product is not chemically pure, the proportion of reagents should be increased to correspond with an equivalent quantity of pure reagent.

Given the analysis of a water, the pounds of incrusting or corrosive matter held in solution per 1000 gallons can be obtained by dividing the grains per gallon of each substance by seven, or the parts per 100,000 by twelve.

By using Table 1, the quantity of reagents per 1000 gallons can be readily calculated, and by applying local cost of the same, the cost for chemicals per 1000 gallons will be obtained. In order to ascertain the full amount of lime necessary, the amount of free carbonic acid contained in the water should be determined, as well as the solids contained in solution, since this free acid must be eliminated in order to obtain efficient treatment of water and reduce scaling matter to the minimum.

TABLE 1. QUANTITY OF PURE REAGENTS REQUIRED TO REMOVE ONE POUND OF INCRUSTING OR CORROSIVE MATTER FROM THE WATER.

Incrusting or Corrosive Substance Held in Solution.	Amount of Reagent (Pure)	Foaming Matter Increased.
Sulphuric acid	0.57-lb. lime plus 1.08 lb. soda ash	1.45 lb.
Free carbonic acid	1.27 lb. lime	None
Calcium carbonate	0.56-lb. lime	None
Calcium sulphate	0.78-lb. soda ash	1.04 lb.
Calcium chloride	0.96-lb. soda ash	1.05 lb.
Calcium nitrate	0.65-lb. soda ash	1.04 lb.
Magnesium carbonate	1.33 lb. lime	None
Magnesium sulphate	0.47-lb. lime plus 0.88 lb. soda ash	1.18 lb.
Magnesium chloride	0.59-lb. lime plus 1.11 lb. soda ash	1.22 lb.
Magnesium nitrate	0.38-lb. lime plus 0.72 lb. soda ash	1.15 lb.
Calcium carbonate	3.15 lb. barium hydrate	None
Magnesium carbonate	3.76 lb. barium hydrate	None
Magnesium sulphate	2.62 lb. barium hydrate	None
*Calcium sulphate	2.32 lb. barium hydrate	None

*In precipitating the calcium sulphate, there would also be precipitated 0.74-lb. of calcium carbonate or 0.31-lb. of magnesium carbonate, the 2.32-lb. of barium hydrate performing the work of 0.41-lb. of lime and 0.78-lb. of soda ash, or for reacting on either magnesium or calcium sulphate, 1-lb. of barium hydrate performs the work of 0.18-lb of lime plus 0.34-lb. of soda ash, and the lime treatment can be correspondingly reduced.

NOTE:—Table is based on use of calcium oxide or lump lime. To obtain equivalent value for hydrated lime, multiply lime value shown in table by 1.32.

[13]SPECIFICATIONS FOR SODA ASH TO BE USED IN WATER TREATMENT

Definition

1. Soda ash is the anhydrous normal carbonate of soda.

Classes

2. Soda ash is commercially divided into two classes:
(a) Light; (b) Dense.

3. Dense soda ash shall be rejected.

(I) CHEMICAL PROPERTIES AND TESTS

Sampling

4. The samples shall be a fair average of the shipment, and shall be taken from the surface to the center of package.

The vendor shall take a one pound sample from four packages in various locations in each carload or less and forward to the purchaser. The sample, on receipt by the purchaser, shall be immediately transferred to air-tight containers in which the unused portion shall be stored until the soda ash has been finally accepted or rejected by the purchaser.

Check tests on samples taken from cars at their destination will occasionally be made, and should agree within reasonable limits with initial sample.

Chemical Properties

5. (a) The classes and properties of soda ash shall be determined by standard methods of chemical analysis.

(b) Soda ash shall conform to the following requirements as to chemical composition:

Normal sodium carbonate—95 per cent minimum.

(II) PHYSICAL PROPERTIES AND TESTS

6. The material shall be in dry powdered form and shall be free from lint, chips, ash or other foreign matter.

Fineness

7. A 100 gram sample shall not have more than 0.5 per cent by weight, insoluble in cold distilled water.

(III) PACKING AND MARKING

Packing

9. Soda ash shall be packed in cloth or duck bags of not more than 100 lb. net weight, or in paper bags of not more than 50 lb. net weight.

Marking

10. The name of manufacturer and net weight shall be plainly marked on each package, or attached by tag thereto.

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[13] Adopted, Vol. 23, 1922, pp. 498, 1113.

(IV) INSPECTION, PENALIZATION AND REJECTION

Inspection

11. (a) All soda ash shall be subjected to inspection.

(b) The soda ash may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the soda ash ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance, penalization or rejection of the soda ash in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Penalization

12. All prices shall be based upon the percentage of normal sodium carbonate. If a lower grade is furnished than the one specified, provided it is not less than 80 per cent sodium carbonate, it may be accepted by the purchaser upon the vendor making a rebate equal to percentage of sodium carbonate below the minimum designated.

Rejection

13. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples by the purchaser.

(b) Rejected soda ash shall be returned to the shipper or as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

14. Samples which represent rejected soda ash shall be preserved in air-tight containers for ten working days from the date of test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

[14]SPECIFICATIONS FOR HYDRATED LIME TO BE USED IN WATER TREATMENT

Definition

1. Hydrated lime is a dry flocculent powder resulting from the hydration of quicklime.

Classes

2. Hydrated lime for water treatment is commercially divided into two classes:

(a) High-Calcium;
(b) Calcium.

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[14] Adopted, Vol. 23, 1922, pp. 500, 1113.

Basis of Purchase

3. The particular class of hydrated lime desired shall be specified in advance by the purchaser. *Unless otherwise specified high-calcium lime shall be furnished.*

(I) CHEMICAL PROPERTIES AND TESTS

Sampling

4. The sample shall be a fair average of the shipment. Three per cent of the packages shall be sampled. The sample shall be taken from the surface to the center of the package. A 2-lb. sample to be sent to the laboratory shall immediately be transferred to an air-tight retainer, in which the unused portion shall be stored until the hydrated lime has been finally accepted or rejected by the purchaser. Check tests on samples taken from cars at their destination will occasionally be made, and should agree within reasonable limits with initial sample.

Chemical Properties

5. (a) The classes and chemical properties of hydrated lime shall be determined by standard methods of chemical analysis.

(b) The hydrated lime shall conform to the following requirements as to chemical composition:

High Calcium....Not less than 90 per cent Calcium Hydroxide ($Ca(OH)_2$)
Calcium ....Not less than 85 per cent Calcium Hydroxide ($Ca(OH)_2$)

(II) PHYSICAL PROPERTIES AND TESTS

Fineness

6. A 100-gram sample shall leave by weight a residue of not over 2 per cent on a standard 100-mesh sieve and not over 0.5 per cent on a standard 20-mesh sieve.

(III) PACKING AND MARKING

Packing

7. Hydrated lime shall be packed either in cloth or in paper bags of not more than 50 lb. net weight.

Marking

8. The weight shall be plainly marked on each package, together with the name of manufacturer.

(IV) INSPECTION, PENALIZATION AND REJECTION

Inspection

9. (a) All hydrated lime shall be subject to inspection.

(b) The hydrated lime may be inspected either at the place of manufacture or the point of delivery, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the hydrated lime ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the hydrated lime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Penalization

10. All prices shall be based upon the minimum percentage of calcium hydroxide. If a lower grade is furnished than the one specified it may at the option of the purchaser be accepted upon making a rebate equal to the percentage of calcium hydroxide below the minimum designated.

Rejection

11. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples.

(b) Rejected hydrated lime shall be returned to the shipper or as he may direct. All freight charges to be paid by the shipper in both directions.

Rehearing

12. Samples which represent rejected hydrated lime shall be preserved in air-tight containers for ten working days from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

[15]SPECIFICATIONS FOR QUICKLIME TO BE USED IN WATER TREATMENT

Definition

1. Quicklime for use in water treatment is a material the major part of which is calcium oxide, which will slake on the addition of water.

Grades

2. Quicklime is divided into two grades:

(a) Selected.—Shall be well-burned, picked free from ashes, coke, clinker or other foreign material.

(b) Run-of-Kiln.—Shall be well-burned, without selection. It shall be free from large lumps of unburned or foreign material.

Forms

3. Quicklime is shipped in two forms:
(a) Lump.—Shall be kiln size.
(b) Pulverized.—Shall be reduced in size to pass a ¼-inch screen.

Classes

4. Quicklime for water treatment is divided into two classes:
(a) High-Calcium.
(b) Calcium.

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[15] Adopted, Vol. 23, 1922, pp. 502, 1113.

Basis of Purchase

5. The particular grade, form and class of quicklime desired shall be specified in advance by the purchaser. Unless otherwise specified high-calcium quicklime shall be furnished.

(I) CHEMICAL PROPERTIES AND TESTS

(A) Sampling

Lime in Barrels

6. Quicklime shall be shipped in barrels, or other containers of similar size. At least 3 per cent of the number of barrels shall be sampled. They shall be taken from various parts of the shipment, dumped, mixed and sampled. The samples shall comprise at least 10 shovelfuls taken from different parts of the shipment. The total sample taken shall weigh at least 100 lb. and shall be crushed to pass a 1-inch ring, and quartered to provide a 15-lb. sample for the laboratory.

Laboratory Samples

7. All samples to be sent to the laboratory shall be immediately transferred to an air-tight container in which the unused portion shall be stored until the quicklime shall finally be accepted or rejected by the purchaser.

Check tests on samples taken from car at destination will occasionally be made, and should agree within reasonable limits with initial sample.

(B) Chemical Tests

Chemical Properties

8. (a) The classes and chemical properties of quicklime shall be determined by standard methods of chemical anaylsis.

(b) Samples shall be taken as specified in sections 6 and 7.

(c) Quicklime shall conform to the following requirements as to chemical composition:

Chemical Composition

Properties Considered	High-Calcium		Calcium	
	Selected	Run-of-Kiln	Selected	Run-of-Kiln
Calcium Oxide, per cent	90 (min.)	90 (min.)	85–90	85–90
Calcium Oxide plus Magnesium Oxide, min., per cent	90	85	90	85
Carbon Dioxide, max., per cent	3	5	3	5
Silica plus Alumina plus Oxide of Iron, max., per cent	5	7.5	5	7.5

(II) INSPECTION, PENALIZATION AND REJECTION

Inspection

9. (a) All quicklime shall be subject to inspection.

(b) The quicklime may be inspected either at the place of manufacture or the point of delivery, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works, which concern the manufacture of the quicklime ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the quicklime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Penalization

10. All prices shall be based upon minimum percentage of calcium oxide. If a lower grade is furnished than the one specified it may, at the option of the purchaser, be accepted upon making a rebate equal to the percentage of calcium oxide below the minimum designated.

Rejection

11. (a) Unless otherwise specified, any rejection based on failure to pass the tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples.

(b) Rejected quicklime shall be returned to the shipper or as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

12. Samples which represent rejected quicklime shall be preserved in air-tight containers for ten working days from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

[16]SPECIFICATIONS FOR SULPHATE OF ALUMINA TO BE USED IN WATER TREATMENT

Definition

1. This chemical shall be the commercial product known as Basic Sulphate of Alumina.

(I) CHEMICAL PROPERTIES AND TESTS

Sampling

2. The sample shall be a fair average of the shipment. Five per cent of the packages shall be sampled. The sample shall be taken from the surface to the center of the package. A five-pound sample shall be sent immediately to the laboratory and transferred to an air-tight container in which the unused portion shall be stored until the alumina has been finally accepted or rejected by the purchaser.

Check tests on samples taken from cars at their destination will occasionally be made, and should agree within reasonable limits with initial sample.

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[16] Adopted, Vol. 23, 1922, pp. 564, 1133.

Chemical Properties

3. (a) The chemical properties of basic sulphate of alumina shall be determined by standard methods of chemical anaylsis.

(b) Basic sulphate of alumina shall contain not less than 17 per cent water soluble aluminum oxide *(Al_2O_3)*; 3 per cent by weight of the aluminum oxide shall be in excess of the theoretical amount required to combine with the sulphuric acid present.

(II) PHYSICAL PROPERTIES AND TESTS

4. The material shall be in dry lump form and shall be free from lint, chips, ash or other foreign matter.

(III) PACKING AND MARKING

5. Basic sulphate of alumina shall be packed in cloth or duck bags of not more than 50 lb. net weight, or in barrels or containers of not more than 300 lb. net weight.

6. The name of manufacturer, net weight and percentage of water soluble alumina shall be plainly stenciled on each end of package or marked on tag securely attached thereto.

(IV) INSPECTION, PENALIZATION AND REJECTION

7. (a) All basic sulphate of alumina shall be subjected to inspection.

(b) It may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the sulphate of alumina ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance, penalization or rejection of the alumina in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Penalization

8. All prices shall be based upon the percentage of water soluble aluminum oxide.

If a lower grade is furnished, it may be accepted at the option of the purchaser, provided the deficiency does not exceed one per cent. The contract price to be reduced in the ratio of the deficiency to the 17 per cent of water soluble aluminum oxide specified.

Rejection

9. (a) Unless otherwise specified, any rejection based on failure to pass tests presented in these specifications shall be reported within ten working days from the taking or receipt of sample by the purchaser.

(b) Rejected basic sulphate of alumina shall be returned to the shipper or as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

10. Samples which represent rejected basic sulphate of alumina shall be preserved in air-tight containers for ten working days from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

[17]SPECIFICATIONS FOR SULPHATE OF IRON TO BE USED IN WATER TREATMENT

Definition

1. Sulphate of iron is the ferrous sulphate, the theoretical formula of which is $FeSO_4+7H_2O$.

Classes

2. Sulphate of iron commercially does not have exactly seven molecules of water combined with one molecule of anhydrous ferrous sulphate.

Commercially there are three grades:

(a) Prime green, selects, or stick crystals.
(b) Seconds or bottoms.
(c) Granular or sugar sulphate of iron.

(I) CHEMICAL PROPERTIES AND TESTS

Sampling

4. The samples shall be a fair average of the shipment and shall be taken from the surface to center of each package.

Ten one-pound samples shall be taken from packages in various locations in each carload or less. These samples shall be thoroughly mixed, and then quartered. One-quarter shall then be placed in an air-tight container and submitted to the purchaser's laboratory for tests.

Check tests on samples taken from cars at their destination will occasionally be made, and should agree within reasonable limits with initial sample.

Chemical Properties

5. (a) The chemical properties of the material shall be determined by standard methods of analysis, and the shipments shall conform to the following minimum requirements:

(b) Impurities: Not over 2 per cent.

(c) Anhydrous ferrous sulphate $FeSO_4$: Not less than 53.5 per cent.

(d) Free Sulphuric Acid: Not over .025 per cent.

(II) PHYSICAL PROPERTIES AND TESTS

Physical Properties

6. Shipments of seconds or bottoms shall be rejected. Either Grade (a) or Grade (c) shall be furnished as specified on the purchase order. Unless otherwise specified, Grade (c) shall be furnished.

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[17] Adopted, Vol. 23, 1922, pp. 506, 1113.

(III) PACKING AND MARKING

Packing

7. Sulphate of iron shall be packed in cloth or duck bags of not more than 100 lb. net weight, or in barrels or containers of not more than 250 lb. net weight as specified in purchase order.

Marking

8. The name of the manufacturer, net weight and grade of sulphate of iron shall be stenciled on each package, or marked on tag securely attached thereto.

(IV) INSPECTION AND REJECTION

Inspection

9. (a) All sulphate of iron shall be subjected to inspection.

(b) The sulphate of iron may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the sulphate of iron ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the sulphate of iron in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection

10. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within 10 working days from the taking or receipt of samples by the purchaser.

(b) Rejected sulphate of iron shall be returned to the shipper or as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

11. Samples which represent rejected sulphate of iron shall be preserved in air-tight containers for 10 working days from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

[18]WATER FOR DRINKING PURPOSES

(1) Federal Interstate Quarantine Regulations, section 13 to Amendment No. 8, as amended July 14th, 1919, and issued by the Public Health Service, provide that water for drinking purposes furnished by railways on cars in interstate traffic shall be pure and from a source which is approved as producing a water of satisfactory sanitary quality and safety

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[18] Adopted, Vol. 21, 1920, pp. 56, 1348.

(2) It is preferable, where available at reasonable cost, that drinking water furnished by railways should be secured from municipal supplies, as these, as a rule, secure close supervision from local and state health authorities.

(3) Where impossible or impracticable to secure potable water from municipal source, precautions should be taken to provide against possible contamination. If supply is secured from wells, local drainage conditions should receive consideration and protection provided against this entering the wells. Surface supplies are particularly susceptible to contamination, and when used should receive standard treatment with bacteriacides such as calcium hypochlorite, chlorine, or ultra violet ray. All such supplies should be tested regularly and if found unfit should be posted with warning—"UNFIT TO DRINK."

[19]SPECIFICATIONS FOR WOODEN WATER TANK

50,000 GALLONS CAPACITY

Material

1. The tank, consisting of staves and bottom plank, shall be made of cypress, redwood, white pine, or such other timber as may be specified by the engineer, and shall be sound, straight-grained, seasoned, out of wind, free from shakes, season checks, sap pitch pockets or streaks, splits, rot, deadwood, unsound knots, loose knots, knots in clusters and large knots extending through the material. Small, loose or unsound knots may be bored out if the holes are thoroughly plugged with the same material as the tank. Material having knots in the edges will not be accepted. No plugs will be permitted within 12 inches of the croze and no stave shall have more than one plug.

Size

2. The tank shall be 24 feet in diameter (inside measurement) and 15 feet 11 inches high. (The height of tank to be the length of finished stave.)

Shape

3. The tank shall be cylindrical, the same diameter at top and bottom.

Bottom

4. The bottom plank shall be 8 to 12 inches wide and not less than 2¾ inches thick jointed two edges, with 3-inch chamfer to fit the croze. All pieces shall be full length without splicing. The bottom shall be cut to the true circle of the tank and the planks marked and numbered to indicate their correct position when the bottom is laid.

Staves

5. The staves shall be 6 to 8 inches wide, and 15 feet 11 inches long, of uniform width throughout with finished thickness of not less than 2¾ inches at edges of stave; the outer side of stave shall be surfaced to the true circle of the tank and edges accurately planed or sawed on radial lines from center of tank. The croze in each stave shall be 4 inches in the clear

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[19] Adopted, Vol. 21, 1920, pp. 71, 1349.

from the end of the stave, the croze to be 2⅝ inches wide with a ⅝ inch gain and shall be accurately cut to fit true circle of bottom.

General

6. (a) The tank shall be framed and jointed in such a manner that all joints may be made watertight without the use of any foreign material.

(b) The staves and bottom plank shall be fitted in a workmanlike manner before shipment, each piece plainly marked to indicate its proper position in the tank.

(c) At least one additional stave shall be shipped with each tank to provide against possible shrinkage or damage.

(d) To facilitate erection the staves may be provided with dowels placed one-third of length of stave from top, dowels to be ¾ inch in diameter and of same material as stave.

100,000 GALLONS CAPACITY

Material

1. The tank, consisting of staves and bottom plank, shall be made of cypress, redwood, white pine, or such other timber as may be specified by the engineer, and shall be sound, straight-grained, seasoned, out of wind, free from shakes, season checks, sap, pitch pockets or streaks, splits, rot, deadwood, unsound knots, loose knots, knots in clusters and large knots extending through the material. Small, loose or unsound knots may be bored out if the holes are thoroughly plugged with the same material as the tank. Material having knots in the edges will not be accepted. No plugs will be permitted within 12 inches of the croze and no stave shall have more than one plug.

Size

2. The tank shall be 30 feet in diameter (inside measurement) and 19 feet 11 inches high. (The height of tank to be the length of finished stave.)

Shape

3. The tank shall be cylindrical, the same diameter at top and bottom.

Bottom

4. The bottom plank shall be 8 to 12 inches wide and not less than 2¾ inches thick jointed two edges, with 3-inch chamfer. All plank 24 feet or less in length shall be full length without splicing. Plank more than 24 feet in length may be made in two pieces to be joined together by means of an iron tongue with suitable slots sawed in the ends of plank to receive the tongue, the tongue to be ⅛ inch in thickness, 6 inches long and the full width of stave. The bottom shall be cut to the true circle of the tank and the planks marked and numbered to indicate their correct position when the bottom is laid.

Staves

5. The staves shall be 6 to 8 inches wide and 19 feet 11 inches long, of uniform width throughout, with finished thickness of not less than 2¾ inches at edge of stave. The outer side of stave shall be surfaced to the true

circle of the tank and edges accurately planed or sawed on radial lines from center of tank. The croze in each stave shall be 4 inches in the clear from the end of the stave, the croze to be 2⅝ inches wide with a ⅝ inch gain and shall be accurately cut to fit true circle of bottom.

General

6. (a) The tank shall be framed and jointed in such a manner that it may be made watertight without the use of any foreign material.

(b) The staves and bottom plank shall be fitted in a workmanlike manner before shipment, each piece plainly marked to indicate its proper position in the tank.

(c) At least one additional stave shall be shipped with each tank to provide against possible shrinkage or damage.

(d) To facilitate erection the staves may be provided with dowels placed one-third of length of stave from top; dowels to be ¾ inch diameter and of same material as stave.

[20]SPECIFICATIONS FOR TANK HOOPS

Material

The tank hoops shall preferably be wrought iron. They may be open-hearth steel. Such wrought iron or steel shall fulfill all of the requirements of quality, strength, inspection and test for wrought iron and open-hearth steel given in the Specifications for Steel Railway Bridges of the American Railway Engineering Association.

Shape

2. Hoops to be round in cross-section the same size throughout and shall be bent to a true radius to fit the tank.

3. To be of such a size and so spaced that the stress shall not exceed 12,500 lb. per square inch, when computed from area at base of thread. No hoop less than ¾ inch diameter to be used.

Spacing

4. Spacing of hoops to be figured by the following formula:

$$\text{Spacing of hoops in inches} = \frac{\text{Safe load for given hoop in lb.}}{2.6 \text{ diameter (ft.)} \times \text{depth,* (ft.)}}$$

Top hoop to be placed within two inches of top of staves. No space between hoops to exceed 21 inches. Hoops to be so placed that lugs will not come in a vertical line.

On account of the swelling of the tank bottom the hoops near the bottom may be subjected to a strain greater than that due to the water pressure alone, therefore additional hoops should be provided. Two hoops of the size used next above it should be placed around the bottom opposite the croze, one of which shall not be considered as withstanding any water pressure.

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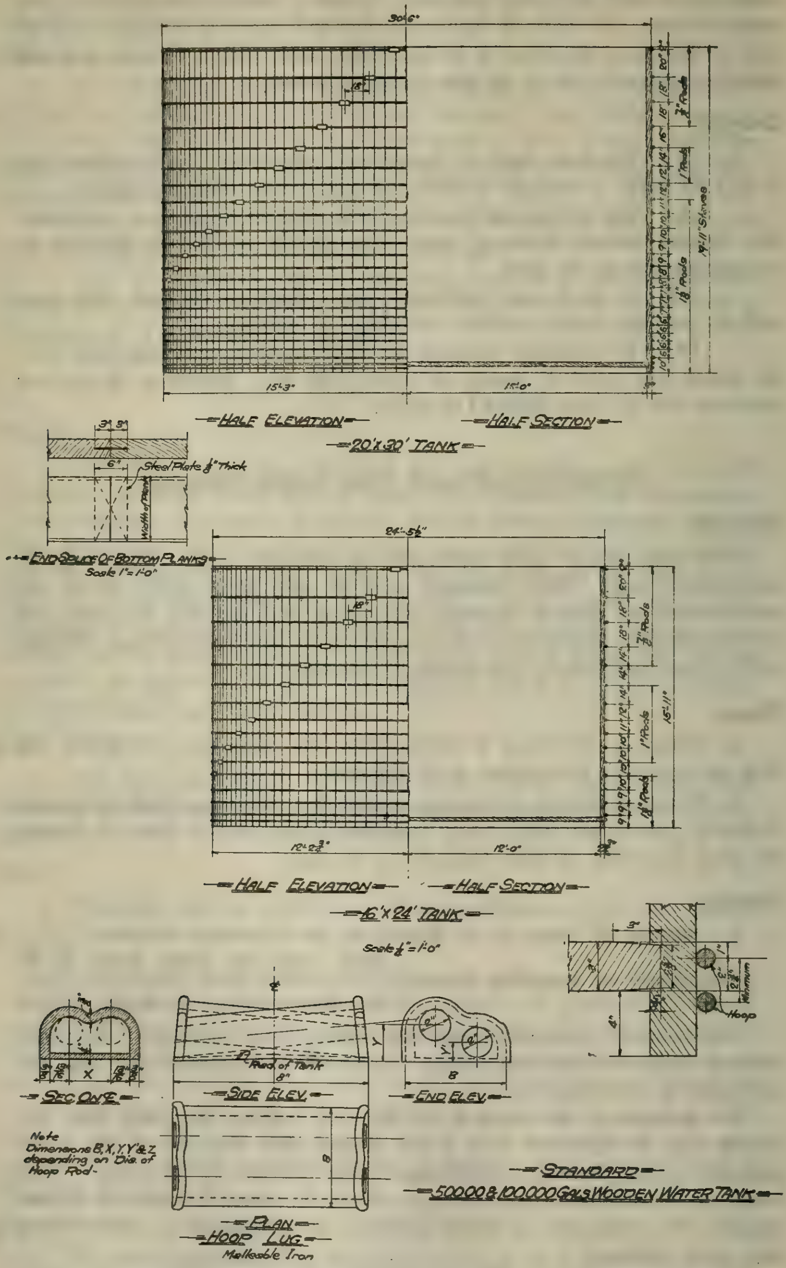
*NOTE.—Depth refers to distance from top of stave to point where hoop is to be located.

[20] Adopted, Vol. 21, 1920, pp. 78, 1348.



Standard 50,000 and 100,000-Gallon Wooden Water Tank

Threads

5. The ends of each section of hoop shall be threaded with United States standard thread for length of 4½ inches.

Nuts

6. Each end of each section shall be provided with two 2 hexagon nuts tapped to fit the thread on hoop.

Lugs

7. The lugs shall be of standard pattern, at least 8 inches long and as strong as the hoop; they shall preferably be made of malleable iron, but cast iron may be used if approved by the engineer.

General

8. Each hoop shall be made in 3 sections for 16 foot by 24 foot tanks and in 4 sections for 20 foot by 30 foot tanks.

The several pieces constituting one hoop shall be tied together for shipment.

All pieces shall be furnished in full lengths, unwelded, and must not vary from the lengths given on order more than ½ inch.

NOTE.—Following table gives proper working strength for hoops of common sizes, based on the above allowable stress:

Diameter of Round Rod, Inches.	*Area of Section of Rod, Square Inch.*	*Net Area of Root of Thread, Square Inch.*	*Safe Working Load, Pounds.*
¾	.44	.30	3,750
⅞	.60	.42	5,250
1	.79	.55	6,875
1⅛	.99	.69	8,625

[21]STEEL SUB-STRUCTURES FOR WATER TANK

50,000 AND 100,000 GALLONS CAPACITY

General

1. The structure will consist of a twelve post steel tower, complete in all details as shown on attached plan for supporting a wooden water tank of the specified size and capacity at the required elevation. The intent of the plans and specifications is to include all material required between the top of foundation and the bottom of tank.

Material

2. Except as may be herein noted all metal in the structure will be made in accordance with specifications of the Association as given in Part Second, "Iron and Steel Structures," Manual of Recommended Practice.

Workmanship

3. Except as may be herein noted workmanship on the structure will be performed in accordance with the requirements of the Association as given in Part Second, "Iron and Steel Structures," Manual of Recommended Practice.

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[21] Adopted, Vol. 22, 1921, pp. 434, 1021.

Painting

4. Steel work before leaving the shop shall be thoroughly cleaned and given one good coat of red lead ground in linseed oil or such paint as may be specified by the engineer. Except as herein noted, cleaning and painting shall be done in accordance with specifications of the Association as given in Part Second, "Iron and Steel Structures," Manual of Recommended Practice.

[22]TIMBER SUB-STRUCTURES FOR WATER TANK

50,000 AND 100,000 GALLONS CAPACITY

General

1. The structure will consist of a 12 post timber tank tower complete in all details, as shown on attached plan, for supporting a wooden water tank of the specified size and capacity at the required elevation. The intent of the plans and specifications is to include all material required between the top of foundation and the bottom of tank.

Timber

2. The timber shall be cypress, pine, fir, redwood, or such other timber as may be specified by the engineer, S4S and conforming to the specifications of this Association for No. 1 railroad bridge timber, as given in "Wooden Bridges and Trestles," Manual of Recommended Practice.

Workmanship

3. All workmanship shall be in accordance with "Specifications for Workmanship for Pile and Frame Trestles to Be Built Under Contract," Manual of Recommended Practice.

Metal Details

4. All metal details shall conform to the specifications of the Association as given in "Specifications for Metal Details Used in Wooden Bridges and Trestles," Manual of Recommended Practice.

Painting

5. All exposed woodwork shall be painted with one priming and two finishing coats of such paints and colors as may be specified by the engineer.

Treating

6. Where treated timber is used timber shall be treated with creosote oil in accordance with the requirements of Wood Preservation, Manual of Recommended Practice.

[23]SPECIFICATIONS FOR STEEL WATER AND OIL TANKS

Scope of Specifications

1. These specifications are intended for steel tanks requiring plates not more than ⅝ inch thick.

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[22] Adopted, Vol. 22, 1921, pp. 435, 1021.

[23] Adopted, Vol. 13, 1912, pp. 417-419, 984-988.

Quality of Metal

2. The metal in these tanks shall be open-hearth steel. The steel shall conform in physical and chemical properties to the Specifications for Steel Railway Bridges.

Loading

3. The weight of water shall be assumed to be 63 lb., crude oil 56 lb., and creosote oil 66 lb. per cubic foot. Wind pressure, acting in any direction, shall be assumed to be, in pounds, thirty times the product of the height by two-thirds of the diameter of the tank in feet.

Unit Stresses

4. Unit stresses shall not exceed the following:

(a) Tension in plates, 15,000 lb. per square inch on net section.
(b) Shear plates, 12,000 lb. per square inch on net section.
(c) Shear on rivets, 12,000 lb. per square inch on net section.
(d) Bearing pressure on field rivets, 20,000 lb. per square inch.

Cylindrical Rings

5. Plates forming the shell of the tank shall be cylindrical and of different diameters, in and out, from course to course.

Workmanship

6. Workmanship shall be first class. Plates shall be beveled on all edges for caulking after being punched. The punching shall be from the surface to be in contact. The plates shall be formed cold to exact form after punching and beveling. Rivet holes shall be accurately spaced. Drift pins shall be used only for bringing the parts together. They shall not be driven with enough force to deform the metal about the holes. Power riveting and caulking should be used. A heavy yoke or pneumatic bucker shall be used for power-driven rivets. Riveting shall draw the joints to full and tight bearing.

Caulking

7. The tank shall be made water or oil tight by caulking only. No foreign substance shall be used in the joints. For water tanks, the caulking shall preferably be done on the inside of tank and joint only; but for oil tanks the caulking should be done on both sides. No form of caulking tool or work that injures the abutting plate shall be used.

Minimum Thickness of Plates

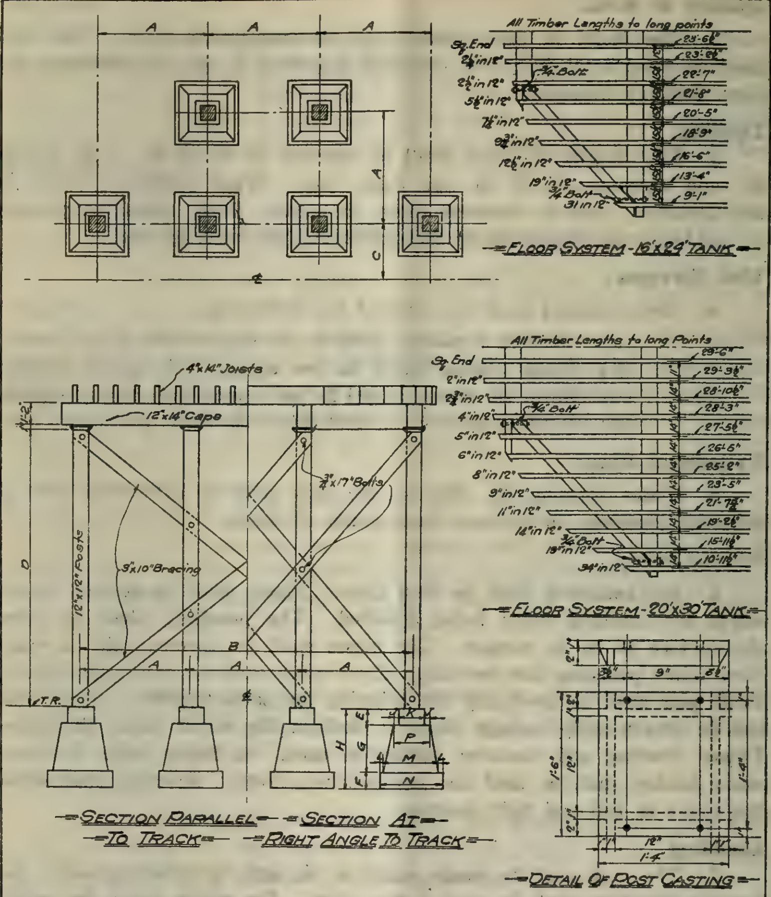
8. The minimum thickness of plates in the cylindrical part of the tank shall be not less than ¼ inch and in flat bottoms not less than 5/16 inch. In curved bottoms the thickness of plate shall be not less than that of the lower plate in the cylindrical part.

Horizontal and Radial Joints

9. Lap joints shall generally be used for horizontal seams and splices and for radial seams in curved bottoms.

Vertical Joints

10. For vertical seams and splices, lap joints shall be used with plates not more than ⅜ inch thick. With thicker plates, double butt joints with



FLOOR SYSTEM - 16'x24' TANK

FLOOR SYSTEM - 20'x30' TANK

SECTION PARALLEL TO TRACK

SECTION AT RIGHT ANGLE TO TRACK

DETAIL OF POST CASTING

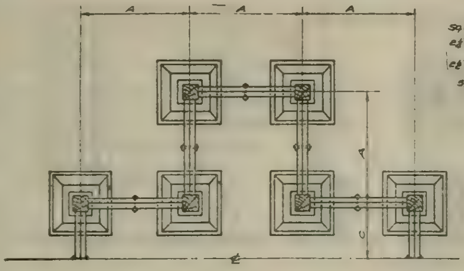
TABLE OF DIMENSIONS & SIZES

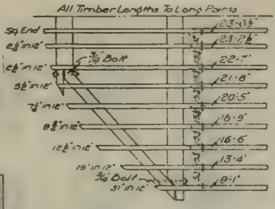
Mark Or Description	SIZE OF TANK 16'x24'		20'x30'	
	16' Tower	20' Tower	16' Tower	20' Tower
A	6'-11"	6'-11"	8'-6"	8'-6"
B	20'-9"	20'-9"	25'-6"	25'-6
C	3'-5½"	3'-5½"	4'-3"	4'-3"
D	13'-5"	17'-5"	13'-5"	17'-5
E	1'-0"	1'-0"	1'-0"	1'-0"
F	1'-0"	1'-0"	1'-6"	1'-6"
G	3'-0"	3'-0"	3'-6"	3'-6"
H	5'-0"	5'-0"	6'-0"	6'-0"
J	0'-5"	0'-5"	0'-5"	0'-5"
K	1'-8"	1'-8"	1'-8"	1'-8"
L	0'-3"	0'-3"	0'-3"	0'-3"
M	3'-6"	3'-6"	4'-6"	4'-6"
N	4'-0"	4'-0"	5'-0"	5'-0"
P	2'-6"	2'-6"	2'-6"	2'-6"
Posts	12"x12"	12"x12"	12"x12"	12"x12"
Braces	3"x10"	3"x10"	3"x10"	3"x10"
Bolts	¾"x17"	¾"x17"	¾"x17"	¾"x17"

NOTE:-
The footing detail as given represents an average condition.
Measurement "N" will be governed by soil conditions but in no case to exceed 3000#/□'

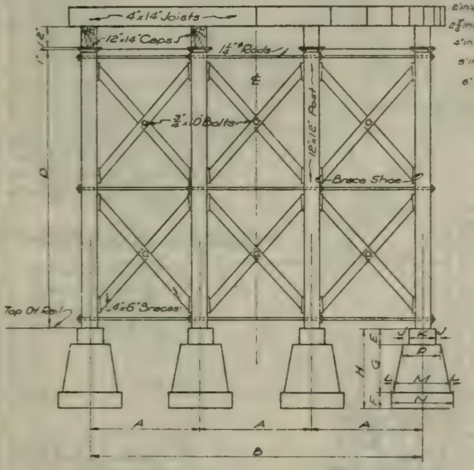
STD. TIMBER 12 POST WATER TANK TOWER
DIAGONAL PLANK BRACING.
FOR 16'x24' & 20'x30' TANKS
16'-0" & 20'-0" HEIGHTS

Scale-None
Sept. 16, 1920

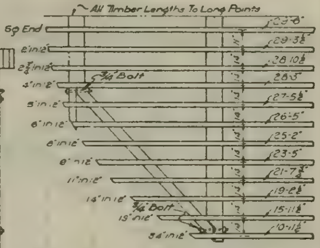




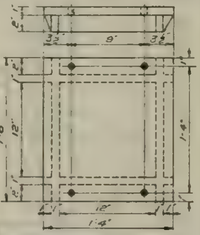
—FLOOR SYSTEM - 16'x24' TANK—



—HALF SECTION— —HALF ELEVATION—



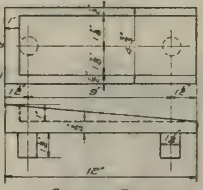
—FLOOR SYSTEM-20'x30' TANK—



—DETAIL OF POST CASTING—

TABLE OF DIMENSIONS & SIZES				
Mark Or Description	SIZE OF TANK			
	16'x24		20x30	
	16 Tower	20 Tower	16 Tower	20 Tower
A	6-11"	6-11"	8-6"	8-6"
B	20-9"	20-9"	25-6"	25-6"
C	3'-5½"	3'-5½"	4-3"	4-3"
D	13-5	17-5	13-5	17-5
E	1-0"	1-0"	1-0"	1-0"
F	1-0"	1-0"	1-6"	1-6"
G	3-0"	3-0"	3-6"	3-6"
H	5-0"	5-0"	6-0"	6-0"
J	0-5"	0-5"	0-5"	0-5
K	1-8"	1-8"	1-8"	1-8"
L	0-3"	0-3"	0-3"	0-3"
M	3-6"	3-6"	4-6"	4-6"
N	4-0"	4-0"	5-0"	5-0"
P	2-6"	2-6"	2-6"	2-6"
Posts	12"x12"	12"x12"	12"x12"	12"x12"
Braces	4"x6"	4"x6"	4"x6"	4"x6"
Bolts	¾"x10"	¾"x10"	¾"x10"	¾"x10"
Rods	1¼"x8-6"	1¼"x8-6"	1¼"x8-11"	1¼"x9-11"

NOTE:-
The footing detail as given represents an average condition.
Measurement 'N' will be governed by soil conditions but in no case to exceed 3000#/□'



—BRACE SHOE—

—STD TIMBER 12 POST WATER TANK TOWER
DIAGONAL STRUT BRACING.
—FOR 16'x24' & 20x30 TANKS—
—16'-0" & 20'-0" HEIGHTS—
—Scale None— —Sept 16 1920—

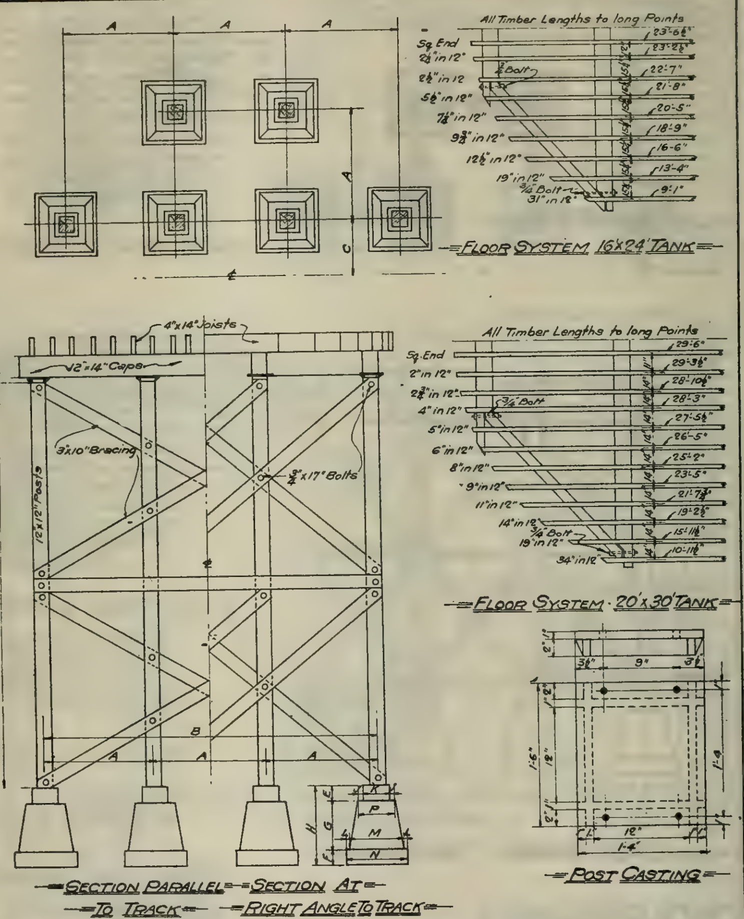


TABLE OF DIMENSIONS		
Mark or Description	30'-0" TOWER	
	SIZE OF TANK	
	16'x24'	20'x30'
A	6'-11"	8'-6"
B	20'-9"	25'-6"
C	3'-5½"	4'-3"
D	27'-5"	27'-5"
E	1'-0"	1'-0"
F	1'-0"	1'-6"
G	3'-0"	3'-6"
H	5'-0"	6'-0"
J	0'-5"	0'-5"
K	1'-8"	1'-8"
L	0'-3"	0'-3"
M	3'-6"	4'-6"
N	4'-0"	5'-0"
P	2'-6"	2'-6"
Posts	12"x12"	12"x12"
Braces	3"x10"	3"x10"
Bolts	¾"x17"	¾"x17"

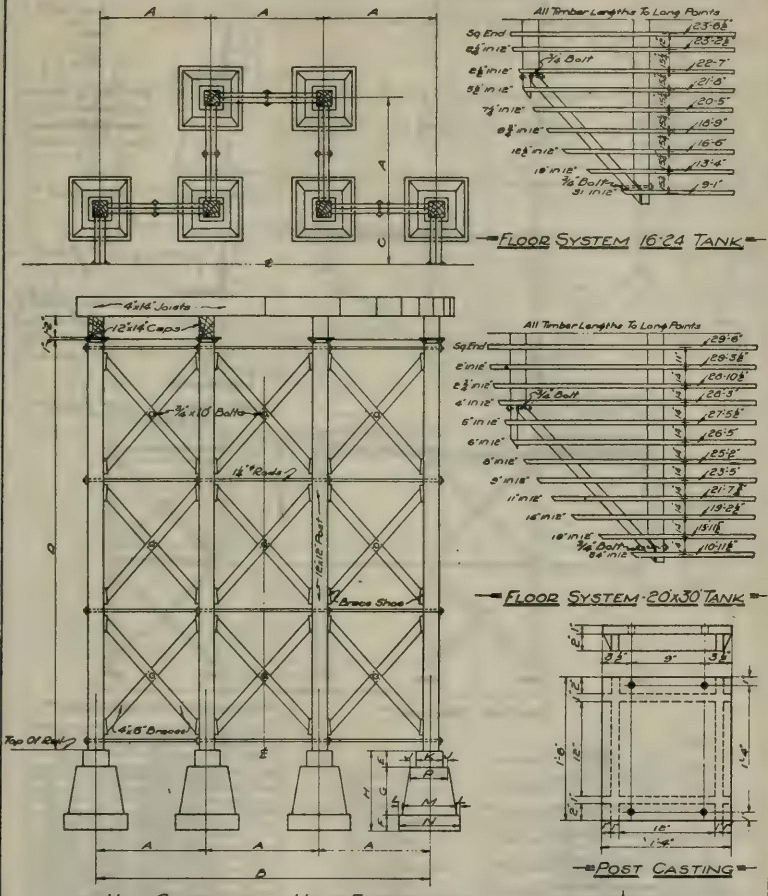
NOTE:-

The footing detail as given represents an average condition

Measurement "N" will be governed to soil conditions but in no case to exceed 3000#/□'

=STD. TIMBER 12 POST WATER TANK TOWER=
=DIAGONAL PLANK BRACING=
=FOR 16x24' & 20x30' TANKS=
=30'-0" HIGH=

Scale-None Sept. 17, 1920

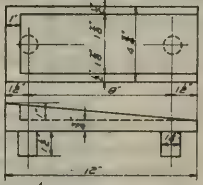


FLOOR SYSTEM 16·24 TANK

FLOOR SYSTEM 20x30 TANK

POST CASTING

HALF SECTION — HALF ELEVATION



BRACE SHOE

TABLE OF DIMENSIONS		
Mark Or Description	30'-0" Tower	
	Size Of Tank	
	16'x24'	20'x30'
A	6'-11"	8'-6"
B	20'-9"	25'-6"
C	3'-5½"	4'-3"
D	27'-5"	27'-5"
E	1'-0"	1'-0"
F	1'-0"	1'-6"
G	3'-0"	3'-6"
H	5'-0"	6'-0"
J	0'-5"	0'-5"
K	1'-8"	1'-8"
L	0'-3"	0'-3"
M	3'-6"	4'-6"
N	4'-0"	5'-0"
P	2'-6"	2'-6"
Posts	12"x12"	12"x12"
Braces	4"x6"	4"x6"
Bolts	¾"x10"	¾"x10"
Rods	1¼"x8'-4"	1¼"x8'-4"

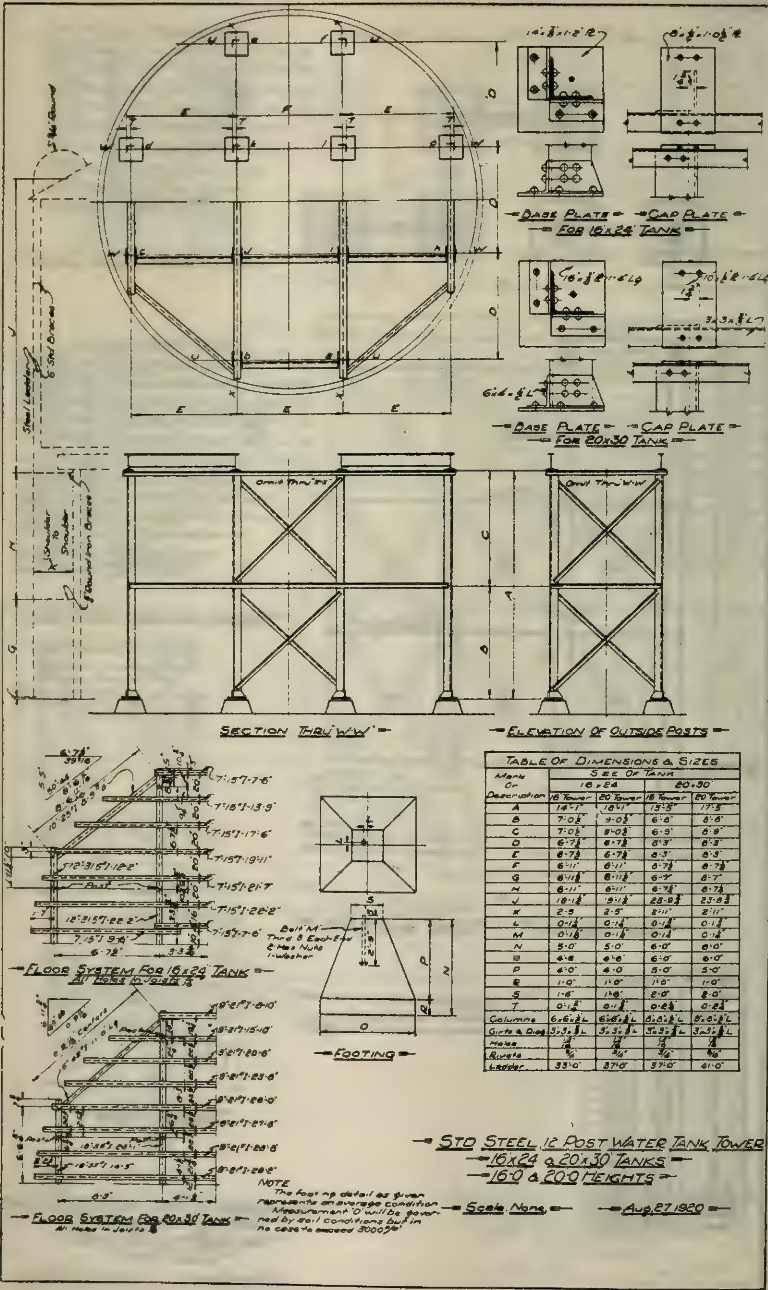
NOTE

The footing detail as given represents an average condition.

Measurement "N" will be governed by soil condition but in no case to exceed 3000#/□'

STD TIMBER, 12 POST WATER TANK TOWER
DIAGONAL STRUT BRACING
FOR 16x24 & 20x30 TANKS
30'-0" HIGH

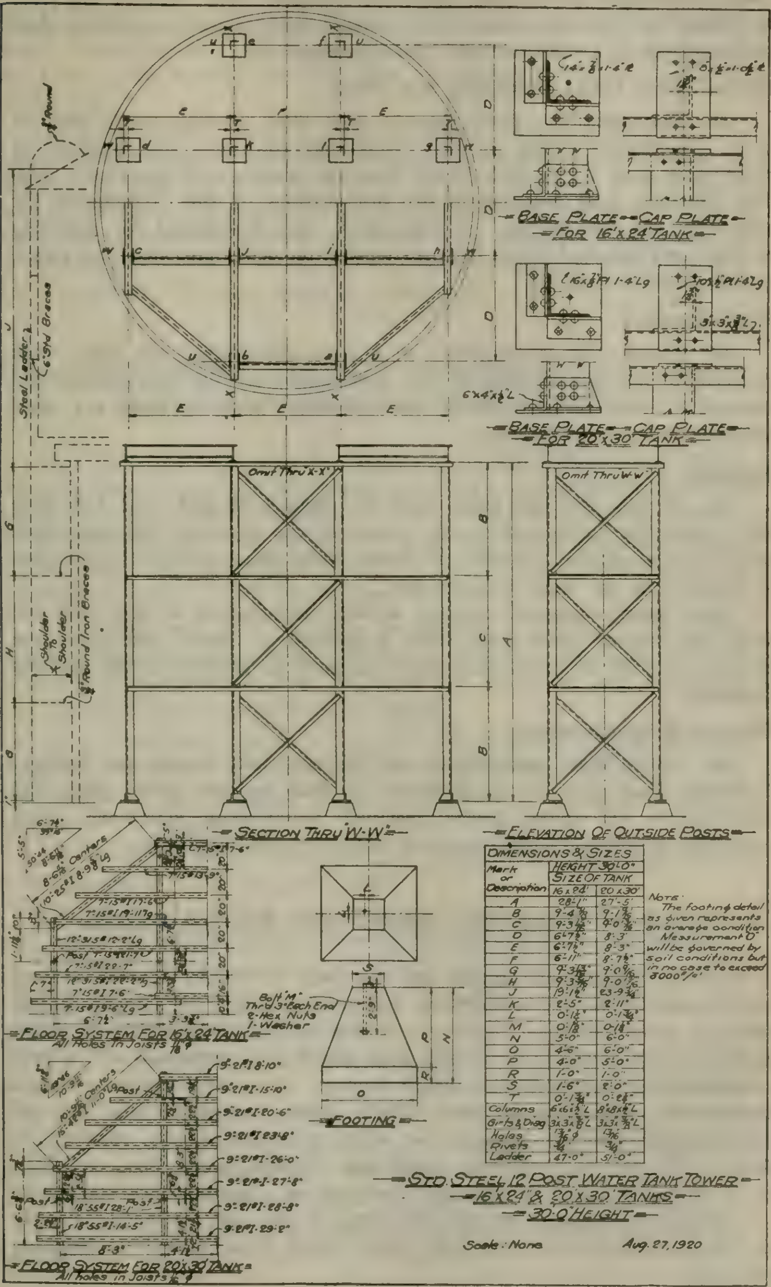
Scale None — Sept 17, 1920


Base Plate
Cap Plate
For 16x24 Tank
Base Plate
Cap Plate
For 20x30 Tank
Steel Ladder
Section Thru W-W
Elevation Of Outside Posts
Omit Thru W-W
Shoulder To Shoulder
Round Iron Braces
Floor System For 16x24 Tank
All Holes In Joists 13/16
Floor System For 20x30 Tank
All Holes In Joists
Footing
Bolt M Thrd 8 Each End 2-Hex Nuts 1-Washer
NOTE
The footing detail as given represents an average condition. Measurement 'O' will be governed by soil conditions but in no case to exceed 3000#/□'

Mark Or Description	Size Of Tank 16x24 16' Tower	16x24 20' Tower	20x30' 16' Tower	20x30' 20' Tower
A	14'-1"	18'-1"	13'-5"	17'-5"
B	7'-0½"	9'-0½"	6'-6"	8'-6"
C	7'-0½"	9'-0½"	6'-9"	8'-9"
D	6'-7½"	6'-7½"	8'-3"	8'-3"
E	6'-7½"	6'-7½"	8'-3"	8'-3"
F	6'-11"	6'-11"	6'-7½"	6'-7½"
G	6'-11½"	6'-11½"	6'-7"	6'-7"
H	6'-11"	6'-11"	6'-7½"	6'-7½"
J	18'-1½"	19'-1½"	23'-8⅞"	23'-8⅞"
K	2'-5	2'-5"	2'-11"	2'-11"
L	0'-1½"	0'-1½"	0'-1½"	0'-1½"
M	0'-1⅛"	0'-1⅛"	0'-1⅛"	0'-1⅛"
N	5'-0"	5'-0"	6'-0"	6'-0"
O	4'-6"	4'-6"	6'-0"	6'-0"
P	4'-0"	4'-0"	5'-0"	5'-0"
R	1'-0"	1'-0"	1'-0"	1'-0"
S	1'-6"	1'-6"	2'-0"	2'-0"
T	0'-1⅝"	0'-1⅝"	0'-2½"	0'-2½"
Columns	6"x6"x½" L	6"x6"x½" L	8"x8"x½" L	8"x8"x½" L
Girts & Diag.	3"x3"x⅜" L	3"x3"x⅜" L	3"x3"x⅜" L	3"x3"x⅜" L
Holes	13/16"	13/16"	13/16"	⅞"
Rivets	¾"	¾"	¾"	¾"
Ladder	33'-0"	37'-0"	37'-0"	41'-0"

STD STEEL 12 POST WATER TANK TOWER
16x24 & 20'x30' TANKS
16'-0 & 20'-0 HEIGHTS

Scale None — Aug. 27 1920



DIMENSIONS & SIZES		
Mark or Description	HEIGHT 30'-0"	
	SIZE OF TANK	
	16 x 24'	20 x 30'
A	28'-1"	27'-5'
B	9'-4 7/8"	9'-1 9/16"
C	9'-3 1/16"	9'-0 1/16"
D	6'-7½"	8'-3'
E	6'-7½"	8'-3"
F	6'-11"	8'-7½"
G	9'-3 13/16"	9'-0 9/16
H	9'-3 5/16"	9'-0 15/16
J	19'-1½"	23-9¼"
K	2'-5"	2'-11"
L	0'-1½"	0'-1¾"
M	0'-1⅛"	0-1⅛"
N	5'-0"	6'-0"
O	4'-6"	6'-0"
P	4'-0"	5'-0"
R	1'-0"	1'-0"
S	1'-6"	2'-0"
T	0'-1¾"	0'-2⅛"
Columns	6"x6"x½" L	8"x8"x½" L
Girts & Diag	3"x3"x⅜" L	3"x3"x⅜" L
Holes	13/16 φ	13/16
Rivets	¾"	¾"
Ladder	47'-0"	51'-0"

NOTE:
The footing detail as given represents an average condition.
Measurement "O" will be governed by soil conditions but in no case to exceed 3000#/□'

STD. STEEL 12 POST WATER TANK TOWER
16'x24' & 20'x30' TANKS
30'-0" HEIGHT

Scale: None
Aug. 27, 1920

inside and outside straps shall generally be used. The edge of the plate in contact at the intersection of horizontal and vertical lap joints shall be drawn out to a uniform taper and thin edge.

Rivets, Rivet Holes, Punching and Pitch

11. For plates not more than ⅜ inch thick, ⅝-inch rivets shall be used. For thicker plates, ¾ inch rivets shall be used. The diameter of rivet holes shall be 1/16 inch larger than the diameter of the rivets used. The punching shall conform to the specifications of this Association for such work on steel bridges. A close pitch, with due regard for thickness of plate and balanced stress between tension on plates and shear on rivets, is desirable for caulking.

Tank Support

12. If the tank is supported on a steel substructure, the latter shall conform to the specifications of this Association for the manufacture and erection of steel bridges, except that allowance shall be made for wind pressure, but not for impact.

Painting

13. In the shop the metal shall be cleaned of dirt, rust and scale and, except the surfaces to be in contact in the joints of the tank, shall be given a shop coat of paint or metal preservative selected and applied as specified by the Railway Company.

After being completely erected, caulked and cleaned of dirt, rust and scale, all exposed metal work shall be painted or treated with such coat or coats of paint or metal preservative as shall be selected by the Railway Company.

Plans and Specifications

14. Under these specifications and in conformity thereto the Railway Company shall cause to be prepared or shall approve detail plans and specifications for tanks, herein specified, as it shall construct. Such plans and specifications shall cover all necessary tank auxiliaries.

[24]USE OF TREATED WOOD FOR WATER TANKS

A lower grade of lumber may be used for tanks if well treated and framed, thus overcoming the increased scarcity of suitable timber used for untreated tanks. The cost of this class of lumber plus the treatment has been found to be considerably less in cost compared with a tank constructed of untreated high grade lumber. It is advantageous from a maintenance standpoint to have a tank, tower, frostproof box, etc., all of creosoted material, making the entire structure equally resistant to decay. The fact that only the metal tank fixtures, hoops, lugs, etc., have to be painted is also an important factor from a maintenance standpoint.

Before a creosoted tub has had time to dry out, it would probably be objectionable for use where the water stored is to be used for drinking purposes.

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[24] Adopted, Vol. 25, 1924, pp. 185, 1249.

A creosoted tub does not readily expand when filled with water and for this reason may call for additional attention to keep staves and floor boards from leaking. Where looks are a factor an untreated timber tub and tower well painted gives a better appearance than an unpainted treated tank.

While no definite data is available as to the maximum life of a creosoted tank and tower, it is known that there are towers over 20 years old still in good condition and tubs still in service which were constructed in the past 16 years. This information coupled with the fact that creosoted lumber has proven satisfactory for many other purposes, would lead to the conclusion that the creosoted tub and tower would last at least as long if not longer than the best untreated timber tank.

[25]HEATING WATER STATION BUILDINGS AND FROST PROTECTION FOR WATER FACILITIES

(1) Frost protection may be affected by drainage, housing and heating, and each method should be used separately or in such combinations as local conditions require, after comparative estimates have been made to establish the most economical and suitable arrangement. These estimates should include interest and depreciation on the first cost as well as maintenance and operating expense for each arrangement considered.

(2) Stoves and hot air furnaces may be used for heating water station buildings where steam generated outside the building is not available. The furnace is an advancement over the stove that should be considered when such buildings are constructed in the future.

(3) Steam may be used to good advantage in the vicinity of power plants, but hot water heat is generally preferable at isolated locations. Sufficient continuity of attendance should be provided at the latter points to keep the fire in proper condition.

(4) Electric heating is generally too expensive in current consumption to be considered, except in special cases.

(5) Housing should be well constructed and frost proofing provided to such extent as justified by the estimates recommended in paragraph 1.

(6) The use of indirect heating to prevent ice accumulation in water tanks instead of direct heating by coils immersed in the water or steam injected into same should be considered.

(7) The use of frost proofing materials and the installation of sealed drainage in water column pits to prevent the inflow of cold air through the drains would, in many cases, benefit the operation of the water columns.

(8) The use of oil instead of coal for heating plant fuel should be considered in sections where coal cost is high or where continuity of attention cannot be conveniently provided for coal firing.

(9) Adequate drainage arrangements should be provided in all freezing latitudes.

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[25] Adopted, Vol. 28, 1927, pp. 230, 1292.

[26]WATER METERS FOR USE IN RAILWAY WATER SERVICE, METHODS FOR TESTING AND READING METERS, AND CHECKING CONSUMPTION OF WATER

Reading Meters

(1) The straight reading indicator consists of revolving discs with figures around their periphery revolving on a common shaft; the figures denoting the meter reading are exposed through a slot in the dial face. This type of indicator requires no instructions, as it is only necessary to copy the figures as shown.

The standard indicator consists of a train of clock gears and pinions, with points indicating on numbered circles or indices the figures which form the meter reading. The standard indicator is in almost general use, as it is much simpler in mechanism and is less liable to get out of order than the straight reading indicator. Accuracy is of the greatest importance in meter reading and familiarity with the work and appearance of the dials under various conditions of moisture, dirt, etc., is necessary to enable the meter reader to do his work accurately.

General Instructions

(2) (a) Before attempting to read a water meter be sure that it is registering. If necessary turn on the water and note if the point of indice moves.

(b) Begin reading the meter by noting the value of the unit in which the dial reads; this is indicated by each indice. These figures indicate the value of one completed revolution of the points, therefore each division of an indice represents one-tenth of the amount marked against each indice. It should be noted that one complete revolution of a point of any indice is equal to one division of the indice of next higher value.

(c) Care must be taken to note the direction of movement of the points which rotate on alternate dials in opposite directions.

(d) Read the indices beginning with the one of lowest value, usually marked 10, and continue in the order shown by the figures beneath each indice, setting down the figures as read, i. e., the reading of the 10 indice in the units column; that of the 100 indice in the tens column, etc.

(e) Always set down the figure on each indice that has been passed last or is just covered by the pointer, as the reading of each indice depends upon the reading of the one of next lowest value. Care must be taken, when the point of the indice being read is close to, or covering a figure, for unless the indice of next lower value has completed a revolution or passed the 0, the pointer which is being read has not completed the division upon which it may appear to rest and the last figure which has entirely passed should be set down on the record.

(f) When the meter has registered its full capacity, that is, one complete revolution of the highest dial, it returns to 0 and starts again.

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[26] Adopted, Vol. 21, 1920, pp. 63, 1348.

Whenever this occurs place in front of the reading of all of the dials the figure 1—this must be done to obtain the present reading.

(g) Dials are made to indicate cubic feet, gallons, liters or any other unit.

ACCURACY OF METERS

Positive displacement water meter when new should test within the following degrees of accuracy:

⅝-inch meters within 2 per cent plus, or minus, on all flows from 20 gallons per minute down to one gallon per minute, and within 10 per cent minus on ¾ gallons per minute.

¾-inch meters within 2 per cent plus, or minus, on all flows from 35 gallons per minute down to 2 gallons per minute and within 10 per cent minus on ½ gallon per minute.

1-inch meters within 2 per cent plus, or minus, on all flows from 60 gallons per minute down to 3 gallons per minute, and within 10 per cent minus on ¾ gallons per minute.

1½-inch meters within 2 per cent plus, or minus, on all flows from 100 gallons per minute down to 5 gallons per minute, and within 10 per cent minus on 1½ gallons per minute.

2-inch meters within 2 per cent, plus, or minus, on all flows from 160 gallons per minute down to 8 gallons per minute, and within 10 per cent minus on 2 gallons per minute.

3-inch meters within 2 per cent plus, or minus, on all flows from 320 gallons per minute down to 16 gallons per minute, and within 10 per cent minus on 4 gallons per minute.

4-inch meters within 2 per cent plus, or minus, on all flows from 560 gallons per minute down to 28 gallons per minute, and within 10 per cent minus on 7 gallons per minute.

6-inch meters within 2 per cent plus, or minus, on all flows from 960 gallons per minute down to 48 gallons per minute, and within 10 per cent minus on 12 gallons per minute.

Testing Meters

The correct method of testing water meters is by weighing the water, allowing 62.5 lb. of water to the cubic foot, and this method should be followed whenever possible. (Variations in volume due to temperature being generally disregarded in actual practice.)

To ascertain the percentage of registration divide 6250 by the number of pounds of water delivered by meter.

To determine the percentage of error in registration, multiply the error in pounds per cubic foot by 16 and divide by 10. It is necessary to run at least one complete revolution of the hand of first indice of the meter dial in all tests, as the graduations of the indice may not be exact.

When necessary to make several runs to complete one revolution of the first indice, the total weight of water delivered in the several runs should be added, and in no case should a sub-division of the circle be used to calculate the accuracy of the meter. When testing a meter, a valve should be placed on the outlet side of the meter and a pressure maintained, making the conditions of test similar to that of actual service.

When the test by weight is impractical meters may be tested in place by using a hose or pipe from the outlet of meter to a test meter of known accuracy.

MAINTENANCE OF METERS

The maintenance of water meters is largely a matter of inspection, testing and cleaning. The total cost of repair parts usually represents but a very small proportion of the expense of maintaining meters.

Where water is furnished through a meter, the meter is generally maintained by the parties furnishing the water, regardless of ownership of meter. In justice to both parties the meter should be maintained as closely as possible to the same degree of accuracy as when received from the manufacturer.

Whenever practical a railroad should standardize its water meters, as this enables employees to so familiarize and perfect themselves in the knowledge of the mechanical construction as to maintain a system of meters at least expense and greatest efficiency.

Hot Water Meters

A hot water meter is similar in construction to a cold water meter except that bronze or similar metal is used for discs, etc., instead of vulcanized rubber, as the hard rubber used in cold water meters becomes pliable at about 120 degrees Fahr. A hot water meter should not be used in continuous service for either hot or cold water, as the metal working parts wear much more rapidly than in the cold water meter where dissimilar substances come in contact.

The principal use of hot water meters is to measure boiler feed water.

Types of Meters Suitable for Railway Service

While all types of meters are used successfully in railway water service, their use may be well confined to two types for general service, namely, the disc and current type of meter.

The disc type of meter is very satisfactory in the smaller sizes and for fairly uniform flow up to three inches. The area of the disc is so great in the larger sizes that they are easily damaged through water hammer; therefore, a current meter should be used for services larger than three inches.

The current or velocity type of meter is designed for the rapid delivery of a large quantity of water, and is a very durable type of meter under heavy duty. The water areas are large as compared to the wearing surfaces and the wear is not as great as with other types of meters even when handling muddy or gritty water.

[27]WATER SERVICE RECORDS

Accurate records of water stations and costs of pumping should be at hand in the office of the official having charge of this branch of the service, and forms M.W. 1301, M.W. 1302, M.W. 1303, M.W. 1304, are recommended for this purpose.

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[27] Adopted, Vol. 10, 1909, pp. 776, 780, 821.

Form 1301

PUMPER'S DAILY REPORT.

—3 Inches— X —3 Inches—

Railway Business

ADDRESS OF OFFICIAL

(Folding Line)

INSTRUCTIONS

Each pumper will fill out one of these reports each day for each plant worked at and forward to

(Name of official)

....

In the supply report fill in the column headed "Balance on hand last day of month" only on the report for the last of the month, showing the supplies on hand at the close of the work on the last day of the month.

PUMPING REPORT

	Hour.	Min.	Hour.	Min.	Hour.	Min.
Time started..						
Time stopped.						
Time ran......						
Counter at start..						
Counter when stopped.						
Dif'rence counter.						
Gage at start..						
Gage when stopped.						
Average gage.....						

(Folding Line)

Pounds Coal used........................

Gallons Gasoline used....................

Other Fuel used..........................

STATION..............................

Date......................19....

Supplies Received		Balance on Hand Last Day of Month
Received To-day	Kind	
	Tons Coal	
	Gal. Gasoline	
	Qt. Gas Eng. Oil	
	Qt. Cylinder Oil	
	Qt. Car Oil	
	Qt. Oil	
	Lbs. Waste	

Pumper

—5½ Inches— X —5½ Inches—

REPORT SIDE ADDRESS SIDE

Size of Card 5½ x 6 inches, printed both sides.

Form 1302

STATEMENT OF COST OF PUMPING WATER

STATION	DATE	TIME PUMP RAN		No Rev. of Counter	Gallons Per Rev	GALLONS PUMPED		Gage Press. in Feet	H.P = Gal. per Min. × Head Feet ÷3960	FUEL REPORTED AS USED			SUPPLIES RECEIVED																COST RECORD INCLUDING LABOR				
													Coal @ $		Gasoline @ $		Other Fuel		Gas Engine Oil @		Cylinder Oil @		Car Oil @		Other Oil @		Waste @						
		Hr.	Min.			Total	Per Min.			Coal Pounds	Gasoline Gallons	Other Fuel	Tons	Cost	Gal.	Cost		Cost	Qts.	Cost	Qts.	Cost	Qts.	Cost	Qts.	Cost	Lbs.	Cost	Labor Cost	Total Mtl.	Per 1000 Gal.	Per Hour	Per H.P Hour

WATER STATION RECORD

AT..

WHERE PAINTING RECORD IS DESIRED ENTER DATE PAINTED WITH PREFIX "P" IN DATE COLUMN.

WHERE SECOND-HAND EQUIPMENT IS INSTALLED ENTER DATE OF MANUFACTURE IN BRACKETS OVER INSTALLATION DATE.

WATER TANKS, SETTLING TANKS INCLUDED								WATER COLUMN											PUMP HOUSE							PUMP PIT				WIND MILLS					
			Tub						Pit				Column																	Tower			Wheel		
Date	Foundation	Substruct.	Diam.	Hght.	Capacity Gallons	Frost Box	Plan Reference	Date	Width	Lght.	Depth	Matl.	Kind	Col. Diam.	Col. Supply	C.Col. Toe Tk	Top Rail to Bot. Spout	Date	Width	Length	Sill to Plate	Foundation	Above Found.	Roof	Date	Size	Depth	Material	Date	Kind	Hght.	Date	Kind	Diam.

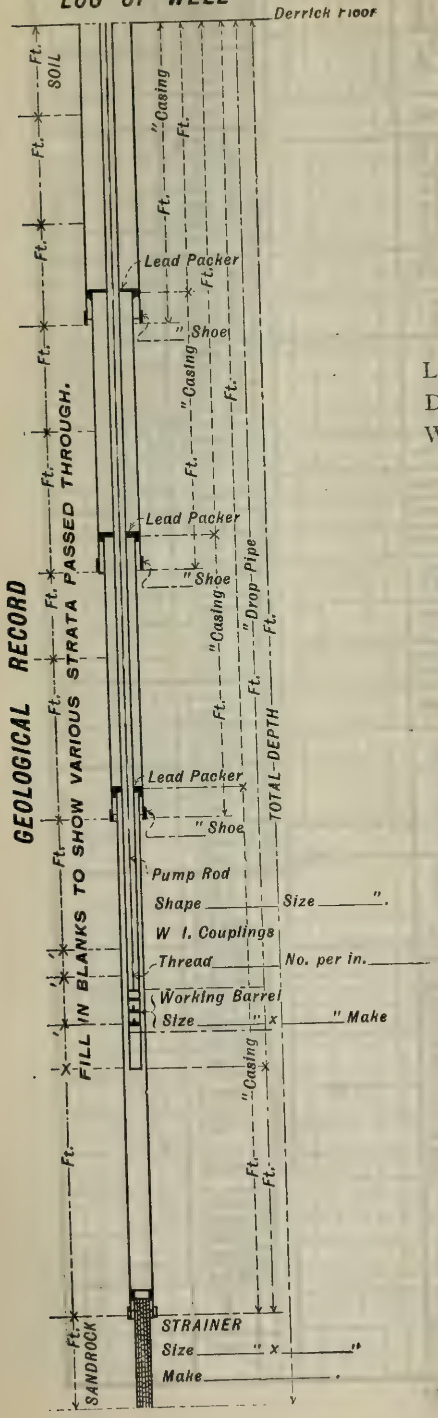
BOILERS													PUMPS									ENGINES					TREATING PLANTS	
	Boiler							Stack			Injector								Size									
				Shell																								
Date Installed	Shop No.	Name Maker	Kind	Lgth	Diam	Size Grate	No. & Size Flues	Date	Diam.	Height	Size	Kind	Date	Maker and Shop Number	Kind of Power	Simplex or Compound Expansion	Single or Double Action	No of Water Cylinders	Steam	Water	Stroke	Date	Maker and Shop Number	Kind	Rated H.P.	Connections from Engine to Pump	Date	Maker and Plan Reference

WATER SUPPLY															HEIGHTS			ANALYSIS		PIPE LINES SEE............FOR LOCATION																			COST RECORD		
		Dug Wells				Pipe Wells									Top Tank to					Steam			Exhaust			Suction			Discharge			Column Supply			Other Lines						
		Diam.						Diam.																																	
Date	Source	Top	Bottom	Total Depth	Material	Date	Number	Top	Bottom	Total Depth	Working Barrel Below Top Well	Kind Point, Screen or Strainer	Make of Packing Head		High Water	Low Water	Center Pump	Lbs incrust. Solids per 1000 gal.	Fitness for Engine Use	Date	Size Kind	Length	Date	Size Kind	Length	Date	Size Kind	Length	Date	Size Kind	Length	Date	Size Kind	Length	Date	Size Kind	Use	Length	Date	Work Done	Original Construction Cost

Form 1303

Form 1304

LOG OF WELL



RECORD OF DEEP WELLS

Location ....

Date began drilling...................................

Well completed ....

WATER LEVELS

Water stands at..................................ft.

And pumps down to...............................ft.

When delivering ....gals per minute.

COMMITTEE XIV

YARDS AND TERMINALS

[1]PASSENGER TERMINALS

DEFINITIONS

CONCOURSE—PASSENGER.—The area adjacent to and on the waiting-room side of the train gates provided for the assembling and dispersal of the traveling public.

—TRAIN.—An auxiliary area on the platform side of the train gates connecting the platforms.

LOBBY.—An area around which ticket windows, parcel and baggage checking windows, information booths and other facilities may be placed.

PASSENGER—SUBURBAN OR COMMUTER.—A short distance traveler rarely requiring auxiliary and incidental service.

—THROUGH.—The long distance traveler usually requiring auxiliary and incidental service.

PLATFORM—BAGGAGE.—A station platform on which baggage, mail and express only are handled.

—HIGH.—A station platform at or near car floor elevation.

—LOW.—A station platform at or near top of rail elevation.

—PASSENGER.—A station platform on which passenger business only is handled.

—STATION.—The prepared area adjacent to a station track for handling passengers and baggage, mail, and express, to and from trains.

RAMP.—An inclined way connecting different levels.

STATION—COMBINATION.—One in which some of the station tracks are connected at one end only and some of the tracks are connected at both ends.

—LOOP.—A form of through station in which the station track layout embraces a loop or part of a circle, trains being moved in one direction only and in the operation turned with reference to the station.

—STUB.—One in which the station tracks are connected at one end only.

—THROUGH.—One in which the station tracks are connected at both ends.

TRACK—STATION.—A track upon which trains are placed to receive or discharge passengers, baggage, mail, and express.

—THROAT.—One of the tracks, connecting station and ladder tracks with main tracks.

WAITING ROOM.—A room equipped with seats and other facilities to accommodate passengers waiting for departing or arriving trains.

YARD—COACH.—A yard in which passenger train cars are assembled, classified and/or prepared for service.

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[1] Adopted, Vol. 28, pp. 559, 1405.

[2]PASSENGER TERMINALS

(1) In designing a passenger terminal it is imperative that provision be made for economical, efficient and continuous operation during the rush hour or period of greatest activity.

(2) The design of a passenger terminal should provide for anticipated demands during at least the first twenty years of its life, and provision should be made for such subsequent expansion as may be reasonable under the circumstances.

(3) The number of station and approach tracks required to handle a given traffic depends on type of station, location of coach and locomotive facilities, size of station, length of station tracks, character of traffic, design of throat, and method of operation.

(4) The track layout should be so designed as to permit the required number of incoming and outgoing movements to be made at one time without interference, with a proper margin for delayed trains, with crossovers so arranged that a derailment will cause a minimum of delay.

(5) Sufficient throat tracks should be provided to permit at least two simultaneous parallel movements. Flexibility sufficient to provide for complete interchange of routes is desirable.

(a) Tracks

(6) A ratio of from 2.5 to 3 station tracks to one throat track should be adequate if the throat is properly designed.

(7) The through and loop types of stations are superior to the stub station from the standpoint of train operation.

(8) For through passenger train operation a stub terminal station will accommodate on an average approximately two trains per track per hour, and a through terminal station between two and three trains per track per hour.

(9) All stations should have a sufficient number of long station tracks to accommodate the longest trains and, in order to assure flexibility of operation, consideration should be given in the design of new stations to the desirability of having all tracks of a length sufficient to accommodate the average length of the longer trains.

(10) Loop tracks for turning trains both in stub stations and in the coach yard, speed up the service and greatly increase capacity, especially for handling suburban business, often at a minimum of expense.

(11) A complete separation of inbound and outbound traffic, particularly in large stations, is very desirable, so that there will be no conflict between lines of travel moving in opposite directions; provided that the design permits of prompt handling of passengers transferring from one train to another.

(b) Platforms—Combined vs. Separate

(12) There are many advantages in the use of separate platforms for trucking and for passengers, as station operation is facilitated and passengers are saved the annoyance of the trucking operations. It is very probable that a station constructed with separate platforms and a corresponding reduc-

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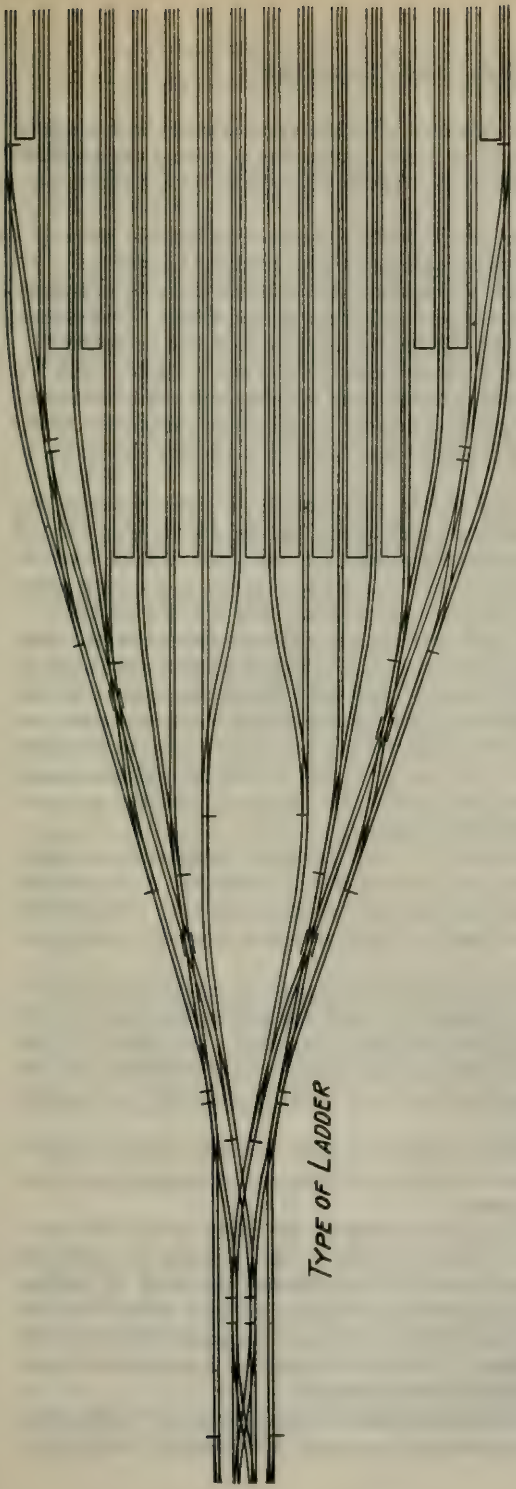
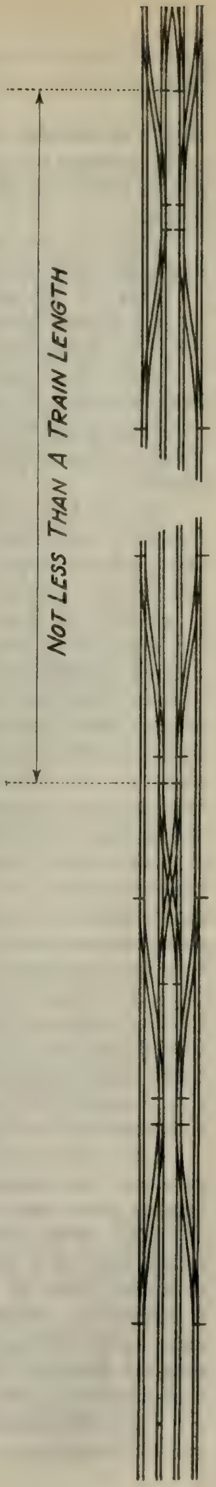
[2] Adopted, Vol. 28, pp. 560, 1407; Vol. 29, pp. 399, 1333.


Type of Ladder


Not Less Than A Train Length

tion in the number of station tracks will have equal capacity with a station which occupies the same area in which combination platforms are provided, due to the increased capacity per track in the station with separate platforms.

(13) In stub stations where trains head into the station, there is a maximum interference between passengers and trucking operations.

(14) If all trains are backed into stub stations there is practically no interference between passengers and trucking operations. Under these conditions combined passenger and baggage platforms should be installed.

(15) If all trains operate in one direction through a station (loop terminal operation) the approaches to and from the concourse can be so located that there would be no interference between trucking and passengers. Under these conditions combined passenger and baggage platforms should be installed.

(16) If the approaches to the concourse in a through station are located in the middle of the station platforms and the station tracks are of only sufficient length to accommodate single trains, there will be interference between passengers and trucking operations; but not to the same extent as would occur in a stub terminal where trains head into the station.

(17) With baggage, mail and express elevators located at the outer ends of the platforms in a through station, where the station tracks are of sufficient length to permit trains to proceed through the station so that baggage, mail and express cars can be spotted opposite the elevators, and the passenger coaches opposite the approaches to the concourse, there will be practically no interference between trucking operations and passengers. With such an arrangement and method of operation combined passenger and baggage platforms should be installed.

(18) In a through station, if two trains are accommodated simultaneously on the same track and trains operated through the station in both directions, the interference which results between passengers and trucking operations is practically the same as occurs in a stub terminal, where trains head into the station.

(19) Other things being equal, the amount of interference between trucking operations and passengers on station platforms increases directly with the amount of passengers and baggage handled. The amount of this traffic should, therefore, be taken into consideration in determining the relative desirability of separate passenger and baggage platforms as compared with combined platforms.

(20) Other things being equal, it is more desirable to have separate passenger and baggage platforms where through and commuter service are handled on the same platforms.

(21) With a seven foot side clearance and track centers 12 feet 6 inches there is a saving in width of right-of-way required for each pair of station tracks of 1 foot 6 inches (not considering the width of column) if columns are located on the platform instead of between tracks. The columns do not increase required width of exclusive passenger platforms more than the width of the column, if it does not result in restricting the space necessary for a given number of lines of travel.

(22) The ratio of the required width of right-of-way for a given number of station tracks with combined passenger and baggage platforms, as

compared with exclusive passenger and baggage platforms is approximately 1.00 to 1.11.

(23) When the station capacity is governed by the arriving rush hour and the operation and design of the station is such that serious interference will result between passengers and trucking, unless the trucking operations are delayed a period of three minutes to permit the majority of the passengers to leave the platform, separate baggage and passenger platforms will increase the capacity of a station developed on a given right-of-way over what it would be if combined passenger and baggage platforms were used. If the capacity of the station is determined by the departing rush hour, the maximum capacity is obtained by the use of combined passenger and baggage platforms. If the capacity of the station is determined by a period in which the number of arriving and departing trains are equal, the capacity is independent of the type of platform used. If the time necessary to delay trucking to avoid interference with passengers is more or less than three minutes, it will correspondingly increase or decrease, respectively, the relative advantages of the separate platforms.

Platforms—Width and Height

(24) A 13-foot exclusive passenger platform is the minimum width sufficient to accommodate the passengers from one arriving train, one line of travel for passengers to a departing train and a row of columns in the center of the platform. A platform of sufficient width to accommodate the passengers from two trains arriving simultaneously adjacent to the same platform is not justifiable.

(25) Exclusive baggage platforms should be of an adequate width to permit two loaded trucks to pass and should be free from columns. A width of 11 feet is recommended as a minimum for exclusive baggage platforms.

(26) Combined passenger and baggage platforms for normal conditions, allowing space on the platform for one loaded truck, should be at least 18 feet in width, assuming a column located in the center of the platform.

(27) In terminal stations, or in stations where a large number of passengers must be handled quickly, it is desirable to build the station platforms at car floor level, as the hazard and inconvenience resulting from the use of car steps are eliminated, and the handling of passengers is expedited. It should be stated, however, that the high platforms interfere to some extent with the switching and inspection of equipment.

(c) Platforms—Approaches—Location

(28) The location of the approaches to the concourse on the station platform in a through station has a bearing on the required capacity of the approach. If it is located at the end of the platform the concentration will be but one-half as intense as if it is located at the middle of the platform, although the duration of the maximum intensity of congestion will be much less in the latter case than in the former. If a double approach is located at the center, the intensity of the concentration will be the same as in the first case and the duration of the maximum intensity of congestion will be the same as in the second case.

Ramps

(29) Ramps furnish ideal means of handling passengers as an approach to passenger platforms if they can be so installed as not to increase materially the distance traveled by passengers, and do not materially decrease the space on the station platform available for the accommodation of trains. Good results can be accomplished in many cases by the use of both stairs and ramps in the approach to the platform.

(30) The gradient for passenger ramps preferably should not exceed 10 per cent. Ramps of this gradient have a carrying capacity approximately as follows:

(a) Through passengers—15 per foot of width per min.

(b) Suburban passengers—30 per foot of width per min.

Elevators and Escalators

(31) Baggage elevators are desirable at both ends of combined passenger and baggage platforms in large passenger stations to reduce the interference between trucking operations and passengers.

(32) Elevators or escalators for heights less than 25 feet are not recommended as approaches to individual passenger platforms. They may be desirable as a supplement to stairs for the use of the aged and invalids.

(33) If instead of one elevator for each platform a battery of elevators can be arranged in sufficient number and approachable from all tracks, as might be possible in a stub terminal, so that a minimum amount of waiting will be occasioned, their use might be justified.

(34) A single elevator or escalator should not be relied upon as the sole means of approach to a passenger platform.

(35) Escalators have a carrying capacity of approximately 33 passengers per foot of width per min. They are well adapted to suburban service, but there is some question as to their practicability for through passenger service.

Stairs

(36) The carrying capacities of stairs decrease with increase in height. For a height of 20 feet the carrying capacities with traffic in one direction are approximately as follows:

(a) For through passengers—10 passengers per foot of width per min.

(b) For suburban passengers—18 passengers per foot of width per min.

(37) In combined passenger and baggage platforms in through stations, it is desirable to have a clearance of approximately 6 feet on one side of the stairs to permit trucking operations past the stairs.

Trucking and Trucking Ramps

(38) High cost of labor justifies the use of power-driven trucks and tractors in connection with trucking operations in large passenger stations.

(39) Ramps are a very desirable means of providing vertical transportation for trucking operations, if the design of the station is such as to permit their installation without a material sacrifice in space.

(40) A gradient of 7 per cent is the steepest yet used to any extent for trucking ramps. This gradient should not be exceeded, though it is possible that trucking ramps may be operated successfully with maximum gradients of 8 per cent.

(41) In stub terminals where separate passenger and baggage platforms are used and the baggage, mail and express facilities are located below the tracks, the utilization of the end of the exclusive baggage platforms adjacent to the concourse permits the installation of trucking ramps without sacrifice of space.

(42) The minimum clear width which should be considered for trucking ramps designed to accommodate one line of traffic is 6 feet and for two lines of traffic is 10 feet.

(d) Principal Facilities—Location

(43) The principal station facilities, such as information booths, ticket office, baggage check counter, parcel check room, etc., should be located in proper sequence along the line of travel and clearly indicated, to avoid confusion and reduce the walking distance of passengers to a minimum.

Concourse

(44) A passenger concourse is desirable and is used effectively in many stations as an exit passageway which permits arriving passengers to reach the street without passing through the station.

(45) The required width of passenger concourse depends upon the character and amount of traffic and the number of entrances and exits from the concourse.

(46) The concourse should be so arranged that it will not be a convenient thoroughfare for people who are not passengers.

(47) A train concourse is advantageous, as it permits serving of one station platform by several train gates or conversely the serving of several platforms from one train gate. In stub stations it permits trucking from one platform to another without entering the passenger concourse.

(48) A width of 20 feet for a train concourse is adequate if it is not used extensively for trucking.

Waiting Room

(49) The waiting room should be located to one side of the line of travel, near the passenger concourse, and be adequately equipped with bulletin boards, clocks, and other information devices, so that passengers will be content to remain in the waiting room and not unnecessarily occupy the passenger concourse.

Ticket Office

(50) Ticket offices should be located adjacent to the direct line of travel, so arranged that passengers waiting to secure tickets will not interfere with the general flow of traffic.

(51) Windows opening directly on to the concourse for the sale of local tickets are desirable.

(52) Where a large number of commutation tickets are issued during the last two or three days of the month, portable booths located in the concourse may be desirable.

Parcel Room

(53) The parcel check rooms should be easily accessible for both inbound and outbound passengers and have facilities for handling parcels quickly. Where the amount of business justifies, separate counters should be provided for receiving and delivering parcels.

Pay Toilets

(54) The practice of installing pay toilets is increasing. They are favorably considered where installed and are the source of a substantial revenue.

Cabs, etc.

(55) The extent of cab facilities depends on the size of the city, character of taxicab service and other means of local transportation. In cities where good taxicab service is provided at a reasonable rate an ever-increasing percentage of passengers is using that service as a means of reaching and leaving the station.

Facilities should be available for making change, so that there need be no delay to taxicabs in unloading passengers and getting away in case passengers do not have the exact fare ready.

Concessions

(56) Concessions for the sale of commodities and the rendering of service catering to the needs and desires of the traveling public, should be provided for the convenience of passengers.

(57) The number and character of these concessions can be greatly expanded in terminals located in cities of large size, with benefit and profit to all concerned.

(58) Concessions, to be successful, must be so located as to be conspicuous and easy of access. They must be neat and attractive in appearance and well lighted, and concessionaries should be experienced, responsible, and progressive.

(59) Booths opening directly on to the corridor where service is rapid, appeal more to the commuter, while stores appeal to the through traveler and particularly to the transfer passenger who has time to spare.

(60) The practice of constructing rentable office space in connection with passenger stations under proper circumstances offers opportunities for assisting in carrying the interest charge resulting from the construction of stations.

(61) If the station building is surmounted by an office building the entrances to the latter should be independent of the station so that office employees will not be required to pass through the station. Consideration, however, should be given in the design of certain station facilities to the possible patronage by occupants of the office building.

(62) Concessions of proper character have proven profitable in most stations and are desirable not only from a revenue producing standpoint, but as a facility which adds to the comfort of the passenger.

Relative Size of Facilities

(63) The relation which should exist between business handled and the size of facilities is subject to variation due to local conditions, class of traffic, type of service rendered, outside competition, large variation in estimates of normal rush-hour business handled and the varying ideas of what constitutes adequate service.

(64) The following Table A represents under average conditions the relation which should exist between business handled and the size of through passenger (not suburban) station facilities.

TABLE A

Relations Which Should Exist Between Business Handled and the Size of Through Passenger Station Facilities

Station Facility	Unit	Number or Size of Facility Required for the Normal Number of Rush-Hour Passengers Indicated									Graph* Number
		250	500	750	1000	1500	2000	3000	4000	5000	
1. Area of main waiting room	100 sq. ft.	30	53	72	89	112	128	155	178	200	5
2. Seating capacity of main waiting room	No. of seats	143	213	270	315	400	465	570	665	750	6
3. Area of women's waiting room	100 sq. ft.	5	7	9	11	14	17	23	29	35	7
4. Area of men's waiting room	100 sq. ft.	5	6	7	8	9	11	14	16	....	8
5. Total area for waiting purposes	100 sq. ft.	55	88	116	137	167	195	238	275	306	9
6. Total seats in waiting areas	No. of seats	190	300	390	470	590	700	880	1050	1200	10
7. Total area of lobby, concourse and all waiting rooms	100 sq. ft.	80	152	208	256	320	376	472	552	624	11
8. Area of men's toilet rooms	100 sq. ft.	4	6	8	10	13	15	20	26	31	12
9. Number of men's water closets	Number	6	9	12	15	19	23	29	35	41	13
10. Number of urinals	Number	5	8	10	12	15	17	20	23	25	14
11. Number of men's lavatories	Number	3	5	7	9	11	13	18	22	26	15
12. Area of women's toilet rooms	100 sq. ft.	3	4	5	6	8	10	13	16	18	16
13. Number of women's water closets	Number	7	9	12	14	17	19	23	27	30	17
14. Number of women's lavatories	Number	3	5	7	9	11	13	17	21	25	18
15. Area of ticket offices	100 sq. ft.	4	7	9	11	14	17	21	26	....	19
16. Number of ticket windows	Number	3	5	7	8	11	13	16	18	21	20
17. Number of telephone booths	Number	3	4	5	7	10	13	19	25	31	21
18. Area of telegraph facilities	Sq. ft.	100	130	150	170	210	230	280	310	330	22
19. Total area of dining and lunch rooms	100 sq. ft.	9	14	19	24	34	43	63	83	102	24
20. Total number of seats in dining and lunch rooms	Number	34	53	72	93	129	173	249	327	407	25
21. Area of kitchen	100 sq. ft.	5	8	11	14	20	26	38	50	62	26
22. Area of news stand	Sq. ft.	115	185	240	290	380	450	565	695	820	28
23. Number of barber chairs	Number	2	3	3	4	4	5	6	7	8	29
	Unit	Baggage Facilities Required for the Indicated Number of Pieces of Baggage Handled Daily									Graph Number
		250	500	750	1000	1500	2000	3000	4000	5000	
24. Area of baggage room	100 sq. ft.	20	33	45	60	87	112	166	219	272	1
25. Baggage room tail-board frontage	Lin. ft.	38	62	79	95	125	150	194	230	263	2
	Unit	Parcel Check Room Facilities Required for the Indicated Number of Parcels Handled Daily									Graph Number
		250	500	750	1000	1500	2000				
26. Area of parcel check room	100 sq. ft.	4	6	8	10	14	18				23
	Unit	Hand-Baggage Facilities Required for the Indicated Number of Pieces of Hand-Baggage Handled Daily									Graph Number
		250	500	750	1000	1500	2000	3000			
27. Area of hand-baggage facilities	100 sq. ft.	4	6	7	8	10	12	16			27

*For graphs, reference is made to Vol. 24, 1923, page 930.

(e) Speed of Passenger Movements

(65) Under normal conditions passengers discharge from trains to station platforms at approximately the following rates per single car exit:

(a) Onto low platforms:
  (1) From Pullmans (after hand baggage has been unloaded)—one passenger every 2.6 seconds.
  (2) From day coaches—one passenger every 3.0 seconds.
  (3) From suburban coaches with exit doors 2.4 feet wide—one passenger every 1.8 seconds.
  (4) From suburban coaches with exit doors 3.4 feet wide—one passenger every 1.4 seconds.

(b) Onto platforms at car floor levels:
  (1) From suburban coaches with exit doors 2.4 feet wide—one passenger every 1.1 seconds.
  (2) From suburban coaches with exit doors 4.0 feet wide—one passenger every 0.8 second.

(66) Speeds of passengers on station platforms under normal and satisfactory conditions are approximately as follows:

(a) When moving unrestricted as individuals:
  (1) Through passengers—4.2 feet per second (2.9 miles per hour).
  (2) Suburban passengers—5.5 feet per second (3.7 miles per hour).

(b) When moving en masse:
  (1) Through passengers—3.7 feet per second (2.5 miles per hour).
  (2) Suburban passengers—5.1 feet per second (3.5 miles per hour).

(67) The platform space utilized by passengers when moving in a compact mass, but without objectionable congestion, is approximately as follows:

(a) Through passengers 15 square feet per passenger moving 220 feet per minute.
(b) Suburban passengers 10 square feet per passenger moving 300 feet per minute.

(68) Capacities of station platforms in discharging passengers are approximately as follows:

(a) Through passengers—15 per foot of width per minute.
(b) Suburban passengers—30 per foot of width per minute.

(69) The rates of movement of suburban passengers which may be expected are approximately as follows:

(a) Through turnstiles (5.3 feet in diameter)—50 passengers per minute.
(b) Through single swinging doors (3.0 feet wide)—77 passengers per minute.
(c) Through double swinging doors (each 3 feet wide)—117 passengers per minute.
(d) Through ticket gates (each ticket punched)—46 passengers per minute.

(f) Characteristics of Passenger Requirements

Through Passenger

(70) Transfer passengers occupy a station for a maximum length of time and require more extensive facilities per passenger than resident through passengers.

(71) Decreasing the time interval between incoming and outgoing trains decreases requirements per passenger for waiting room space and for certain other facilities.

(72) Increased business tends to increase the number of trains, decrease the waiting time, and equalize the spread of minutes-waiting per passenger over the rush hour period.

(73) The number of passengers handled during the rush hour does not alone determine the size or number of facilities required. Local conditions must be studied as they affect requirements for any particular situation.

(74) The size or number of facilities must be modified to make allowance for:

(a) Time of arriving and departing trains, and the span in minutes between them.

(b) The ratio between passengers commencing or terminating their journey and transfer passengers.

(c) Number of holdover passengers arriving or departing outside of the rush hour but occupying space and requiring service during a portion of the rush hour.

(d) Departure from a reasonably uniform spread of passengers entering and departing within the rush hour.

Suburban or Commuter Passengers

(75) Suburban passengers occupy a station for a minimum length of time, occupy less space and move faster than the through traveler and therefore requirements in the way of station facilities per passenger are substantially less for a suburban than for a through traveler.

(76) When suburban business is heavy it is desirable to separate the through and suburban service, as their requirements are not similar. This may be done by handling the two classes of service at:

(a) Different levels. This requires electrification.

(b) At different sides of the station.

(c) At different terminals, one beyond the other.

(77) Exit turnstiles for handling large numbers slow up traffic and should be avoided.

(78) The concourse should be large enough to permit the gathering of a full trainload at a gate without a blockade.

(79) It should be possible for incoming passengers to proceed directly from the concourse to the street without passing through waiting room or blocking its exits.

(80) Indicator boards are the only directional information required, as a rule, by commuters. They should show track number, scheduled leaving time and names of stations at which the train will stop.

(81) In case a departing train is shifted to a track other than the one from which it regularly leaves, a display board should be posted on

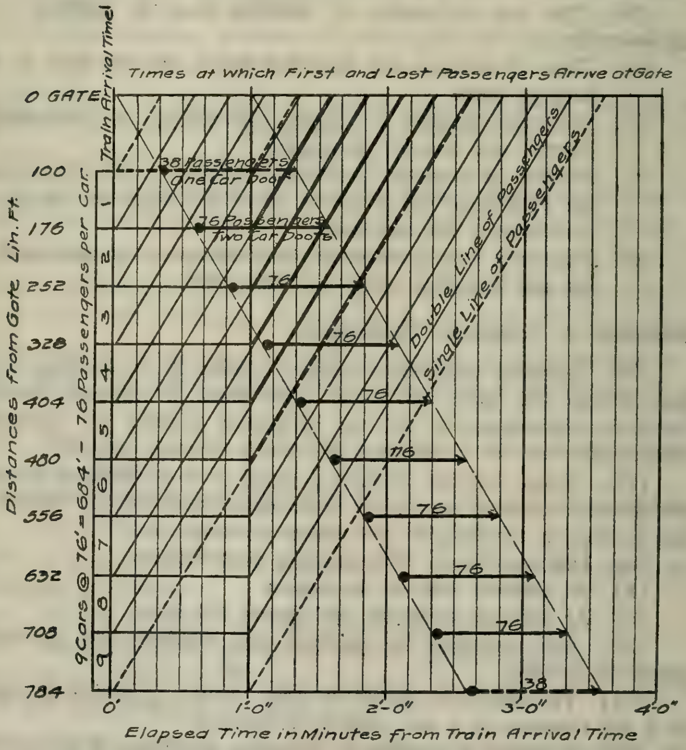
the indicator board for the regular track before that gate is opened and generally not less than five minutes before the actual leaving time.

(82) Posters giving the time for leaving, the regular track number, and the destination of trains, should be displayed at a few conspicuous points in the waiting room and concourse.

TIME REQUIRED TO PASS SUBURBAN PASSENGERS THROUGH GATES OR OVER STAIRS OR RAMPS OF VARYING WIDTHS.

(See Vol. 26, 1925, page 731)

Diagram T

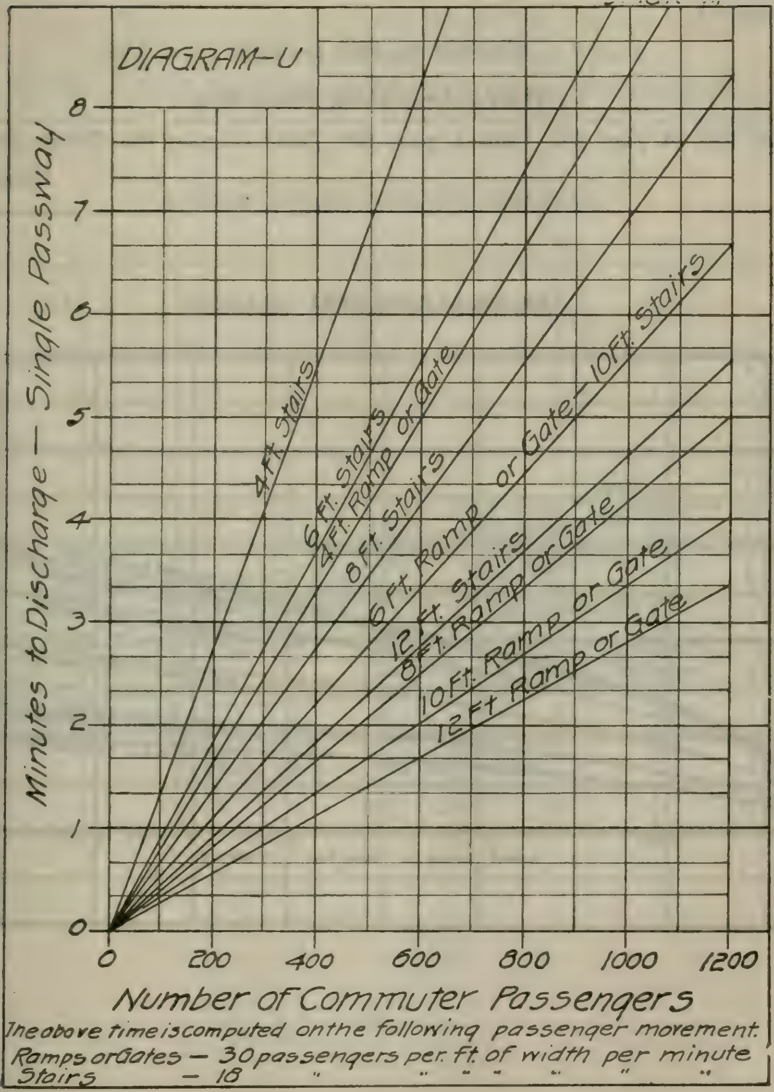


Unloading time—1.6 seconds per passenger.
Traveling time—5.1 feet per second.
Length of arrows indicate time during which passengers from one exit are passing through the gate.
Maximum of 8 lines of passengers through gate at one time.

UNLOADING AND TRAVELING TIME CHART FOR SUBURBAN TRAIN—STUB TERMINAL—LOW PLATFORMS

(See Vol. 26, 1925, page 733)

Diagram U



The above time is computed on the following passenger movement.
Ramps or Gates — 30 passengers per ft. of width per minute
Stairs — 18 " " " " " "

DIAGRAMS SHOWING SIZE OR NUMBER OF FACILITIES REQUIRED FOR VARYING PROPORTIONS OF MIXED THROUGH AND COMMUTER SERVICE

(See Vol. 26, 1925, page 739)

Table 9-A—Waiting Room Area

(See Vol. 24, page 862, Table 2; page 899, Table 11; page 903, Graph No. 9)

Diagrams C

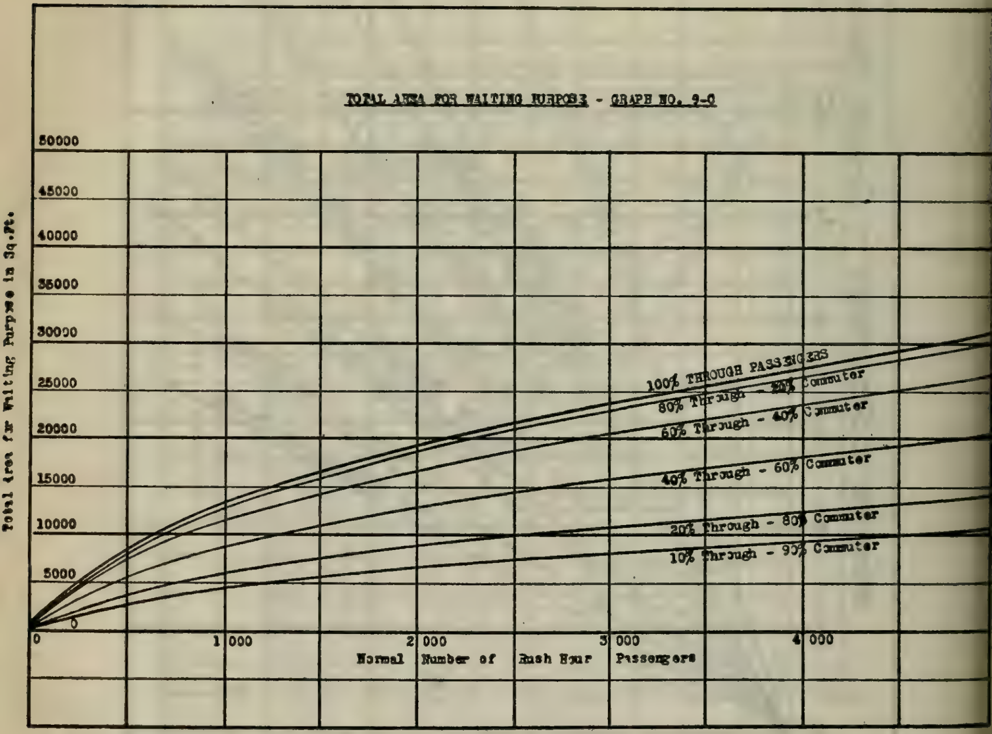


Table 10-A—Seating Capacity of Waiting Rooms

(See Vol. 24, page 862, Table 2; page 901, Table 13; page 904, Graph No. 10)

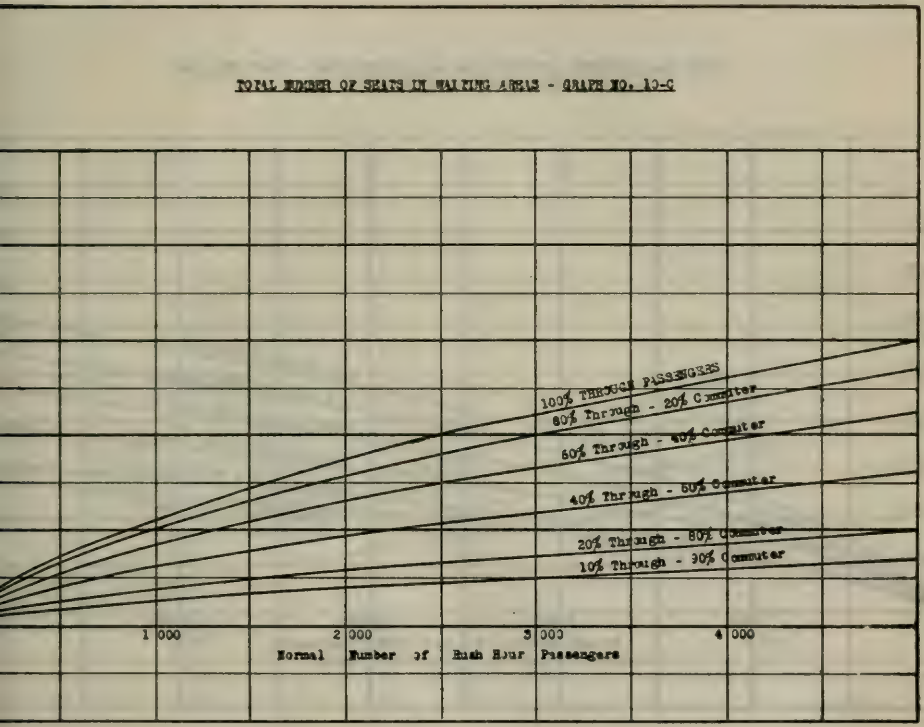


Table 11-A—Summary of Lobby, Concourse, and Waiting-Room

(See Vol. 24, page 862, Table 2; page 900, Table 12; page 904, Graph No. 11)

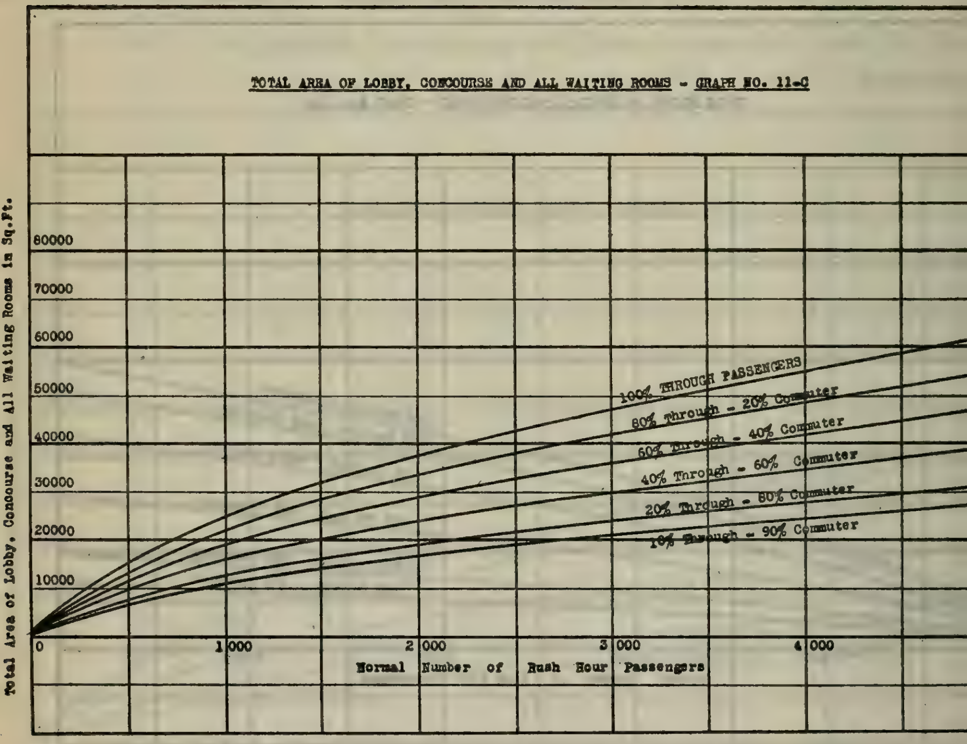


Table 12-A—Area of Men's Toilet Facilities

(See Vol. 24, page 862, Table 2; page 906, Table 14; page 904, Graph No. 12)

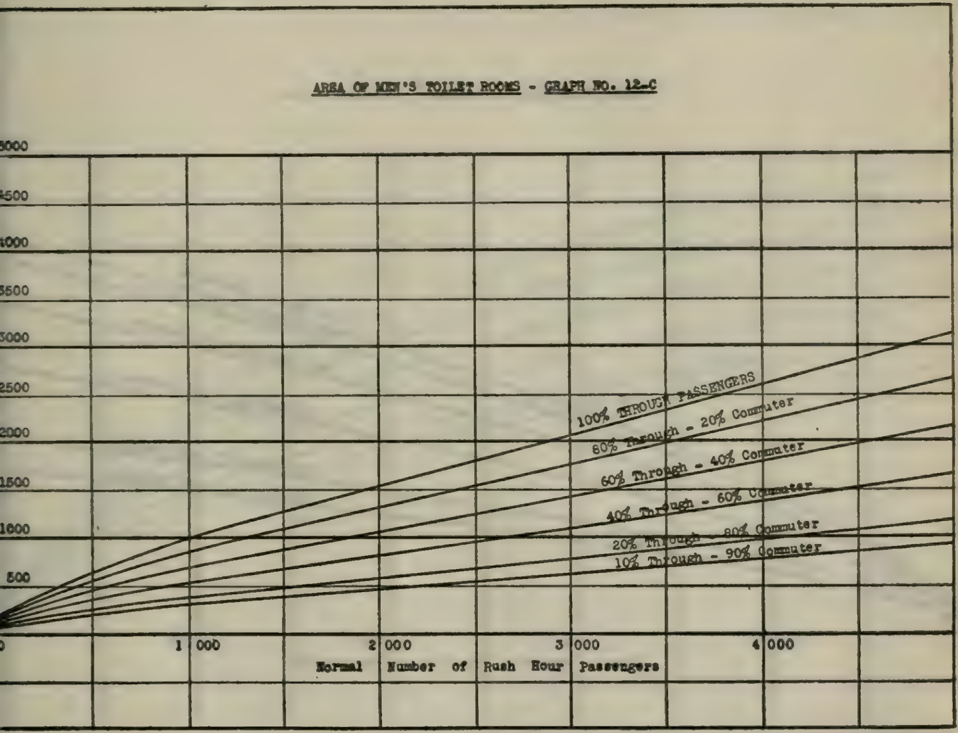


Table 13-A—Number of Men's Water Closets

(See Vol. 24, page 862, Table 2; page 906, Table 14; page 908, Graph No. 13)

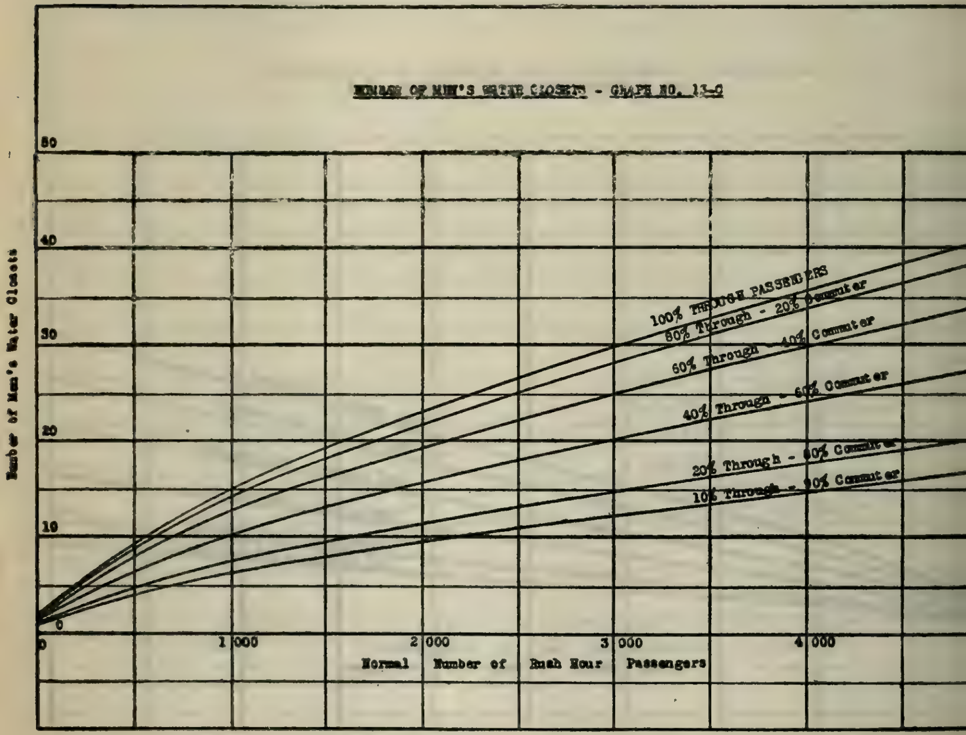


Table 14-A—Number of Men's Urinals

(See Vol. 24, page 862, Table 2; page 906, Table 14; page 908, Graph No. 14)

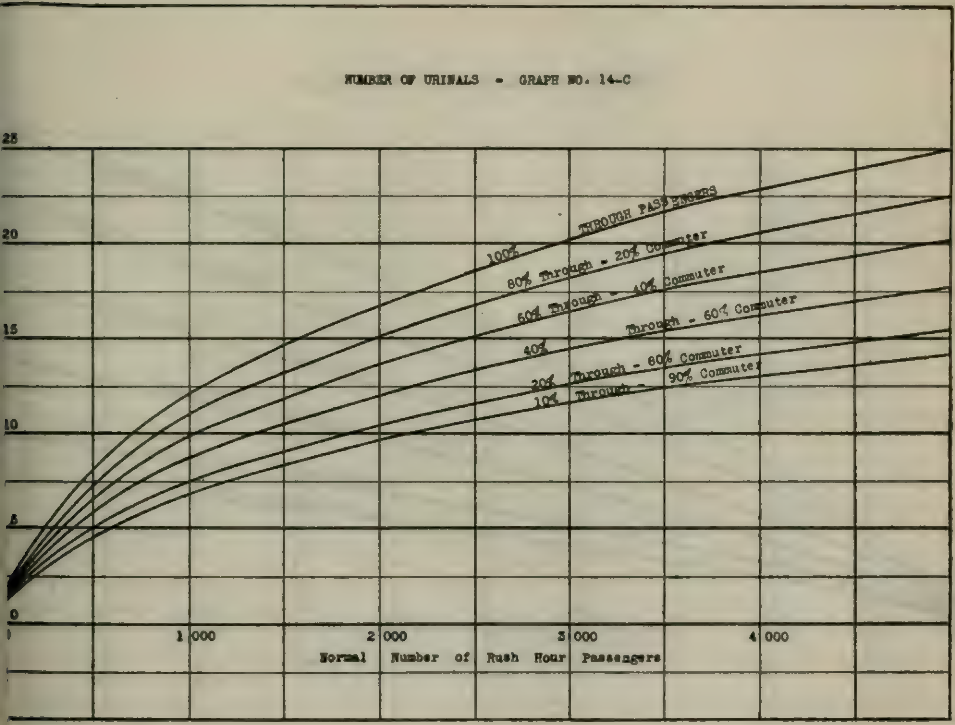


Table 15-A—Number of Men's Lavatories

(See Vol. 24, page 862, Table 2; page 906, Table 14; page 908, Graph No. 15)

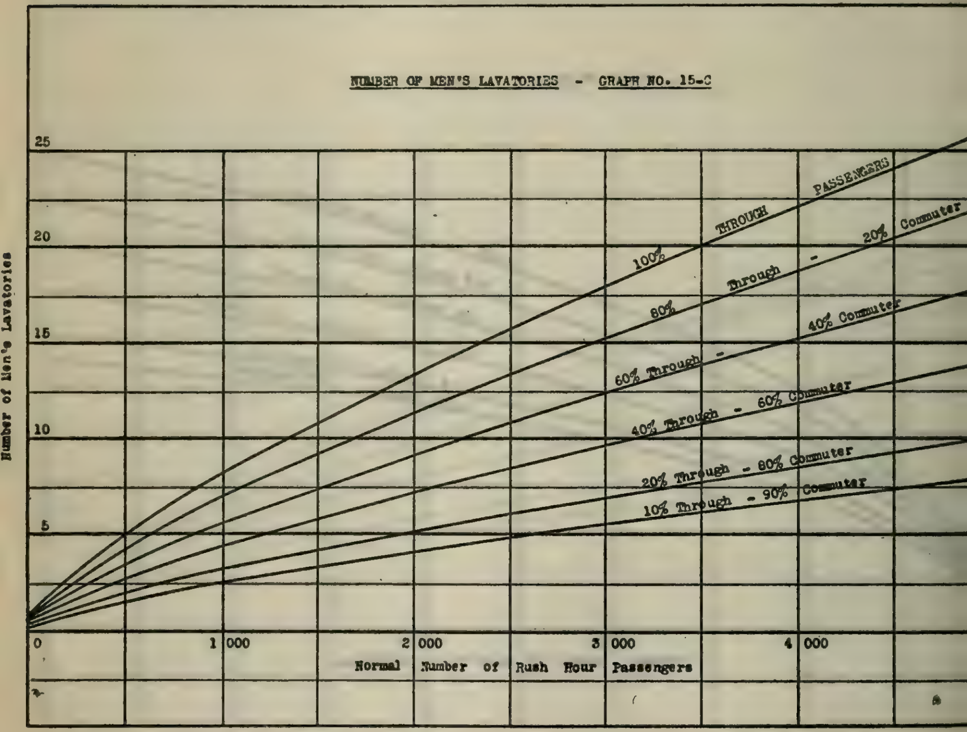


Table 16-A—Area of Women's Toilet Rooms

(See Vol. 24, page 862, Table 2; page 907, Table 15; page 909, Graph No. 16)

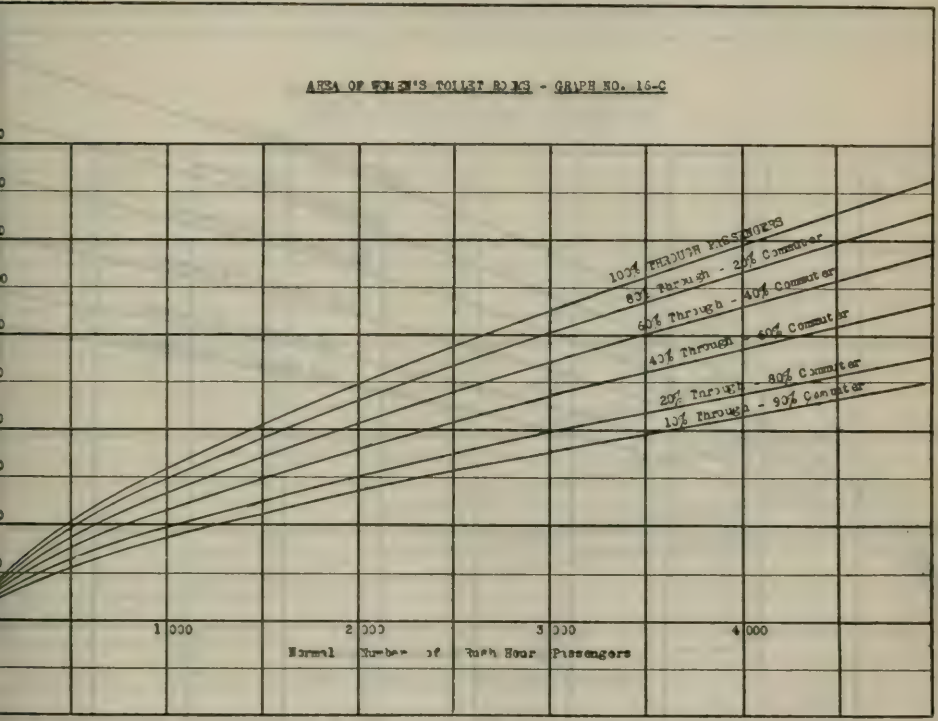


Table 17-A—Number of Women's Water Closets

(See Vol. 24, page 862, Table 2; page 907, Table 15; page 909, Graph No. 17)

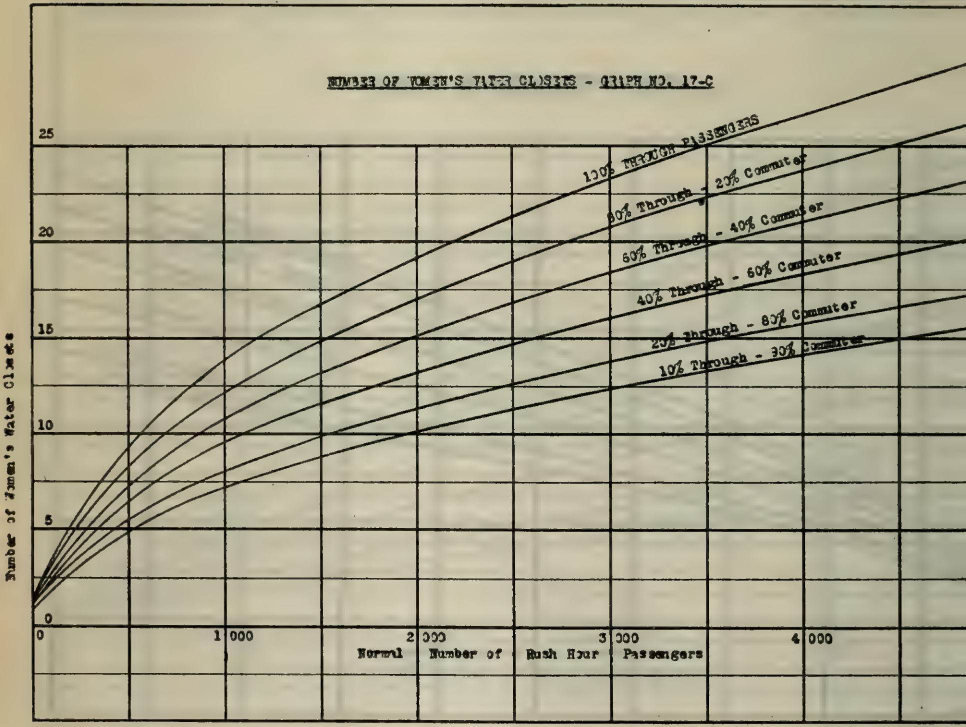


Table 18-A—Number of Women's Lavatories

(See Vol. 24, page 862, Table 2; page 907, Table 15; page 909, Graph No. 18)

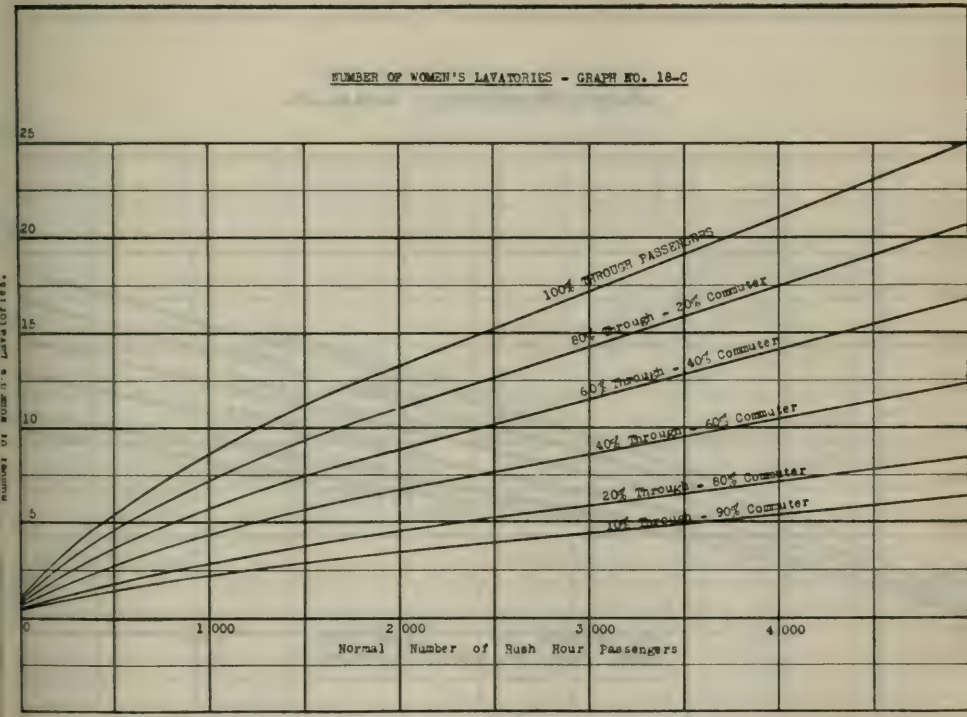


Table 19-A—Area Ticket Office Space

(See Vol. 24, page 862, Table 2; page 910, Table 16; page 913, Graph No. 19)

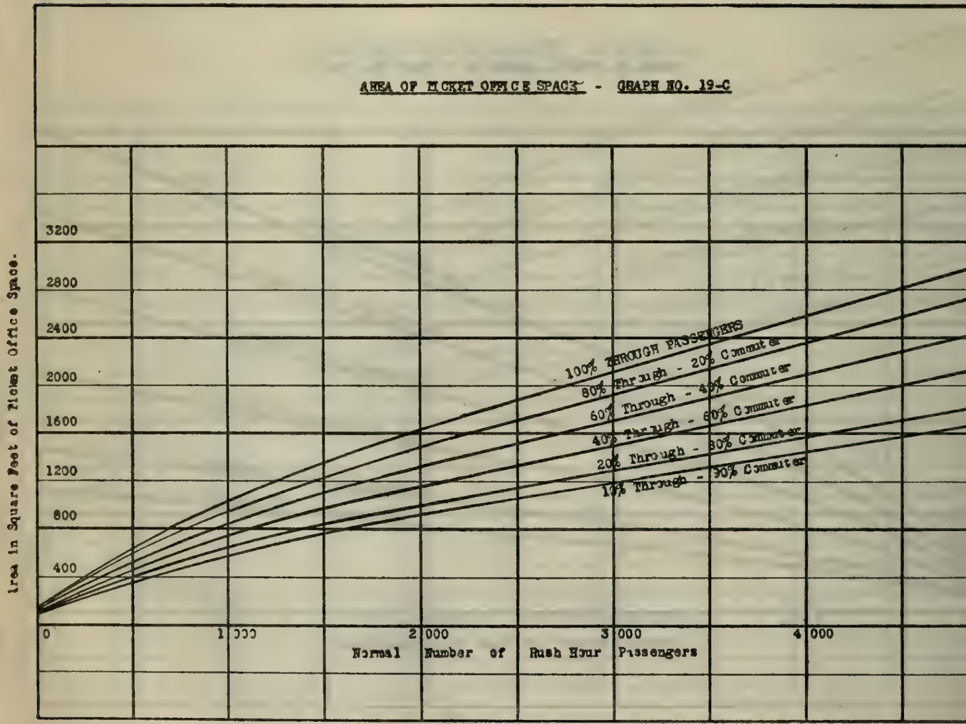


Table 20-A—Number of Ticket Windows

(See Vol. 24, page 862, Table 2; page 910, Table 16; page 913, Graph No. 20)

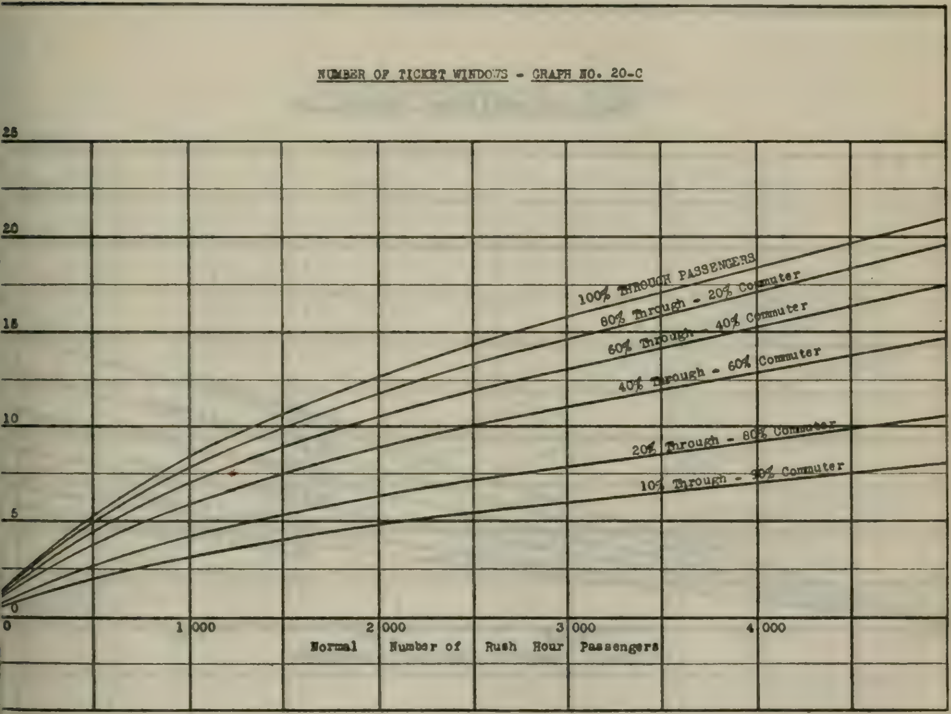


Table 21-A—Number of Telephone Booths

(See Vol. 24, page 862, Table 2; page 912, Table 17; page 913, Graph No. 21)

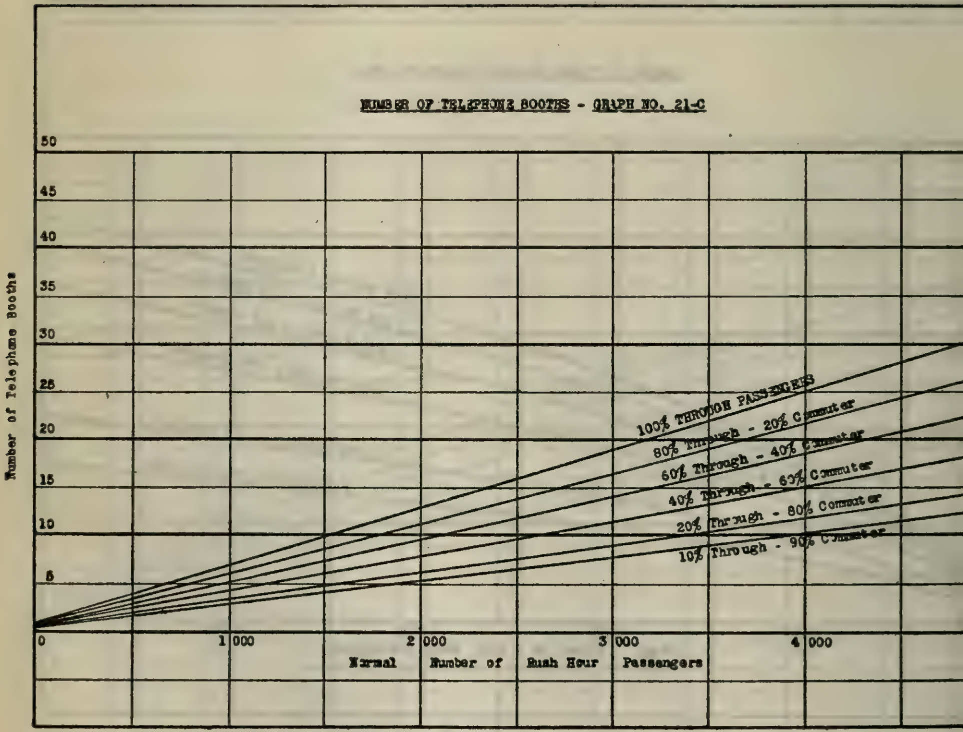


Table 24-A—Area of Dining and Lunch Rooms

(See Vol. 24, page 862, Table 2; page 916, Table 19; page 914, Graph No. 24)

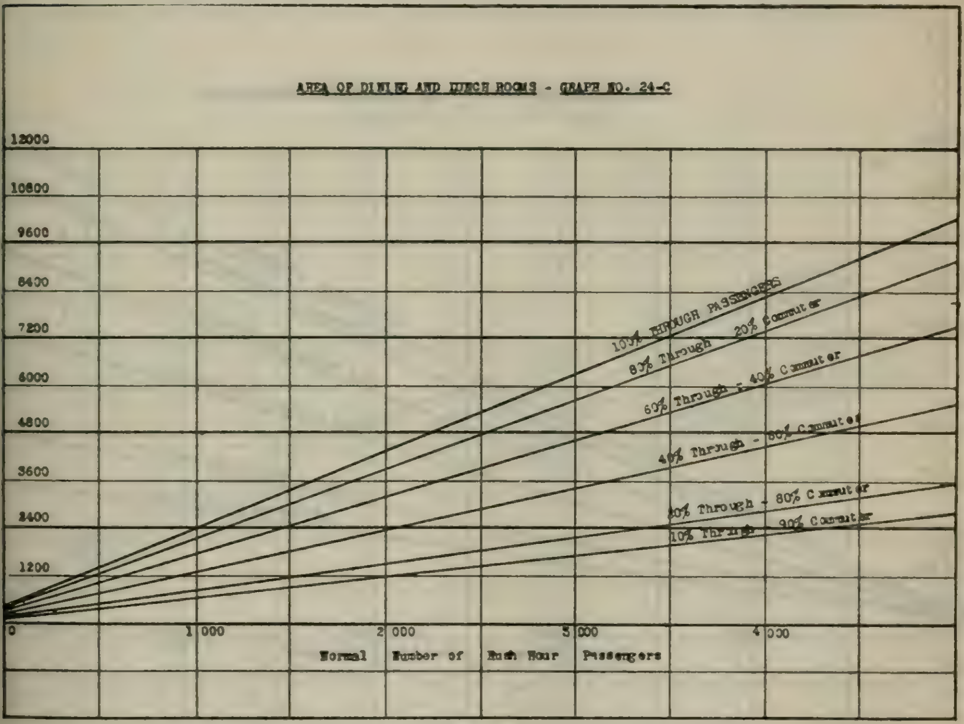


Table 25-A—Seating Capacity of Dining and Lunch Rooms

(See Vol. 24, page 862, Table 2; page 917, Table 20; page 922, Graph No. 25)

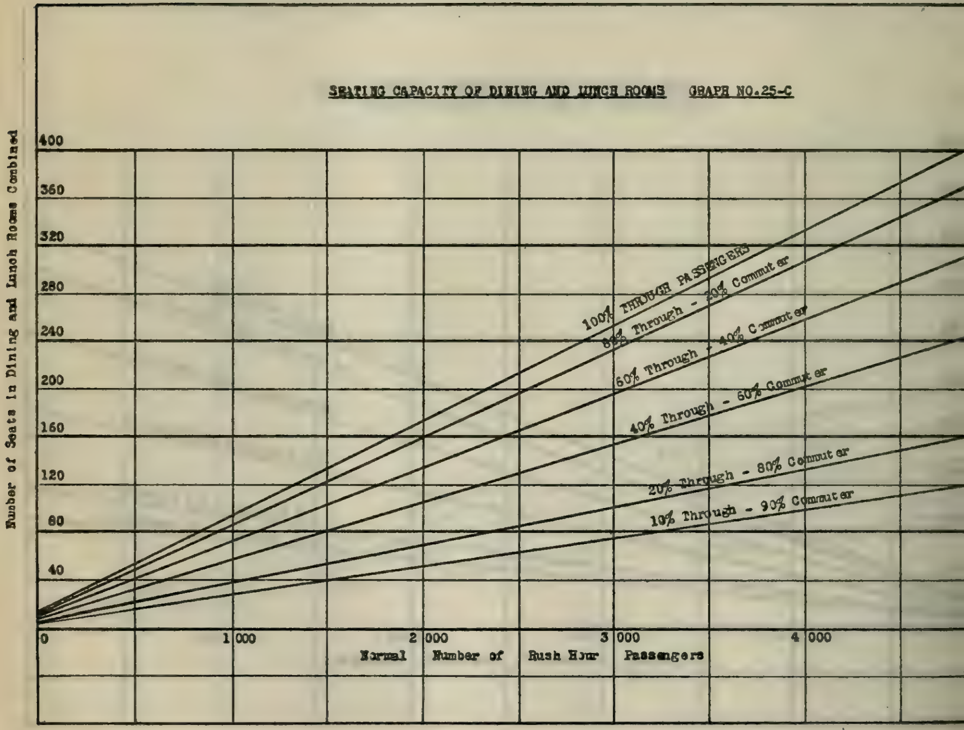


Table 28-A—Areas of News Stands

(See Vol. 24, page 862, Table 2; page 924, Table 23; page 926, Graph No. 28)

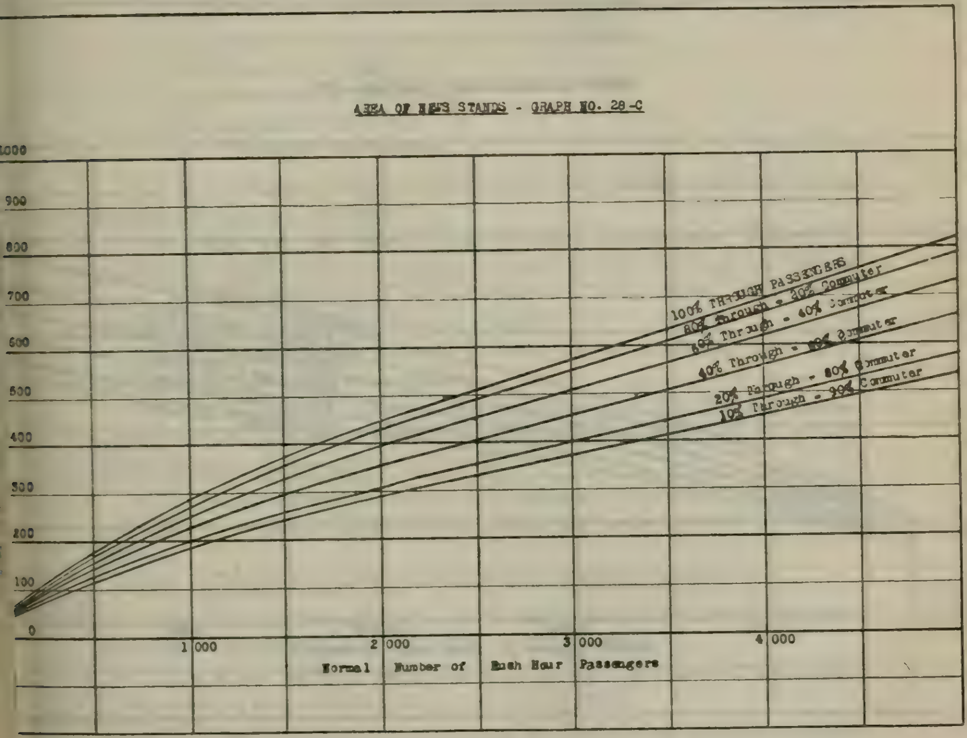
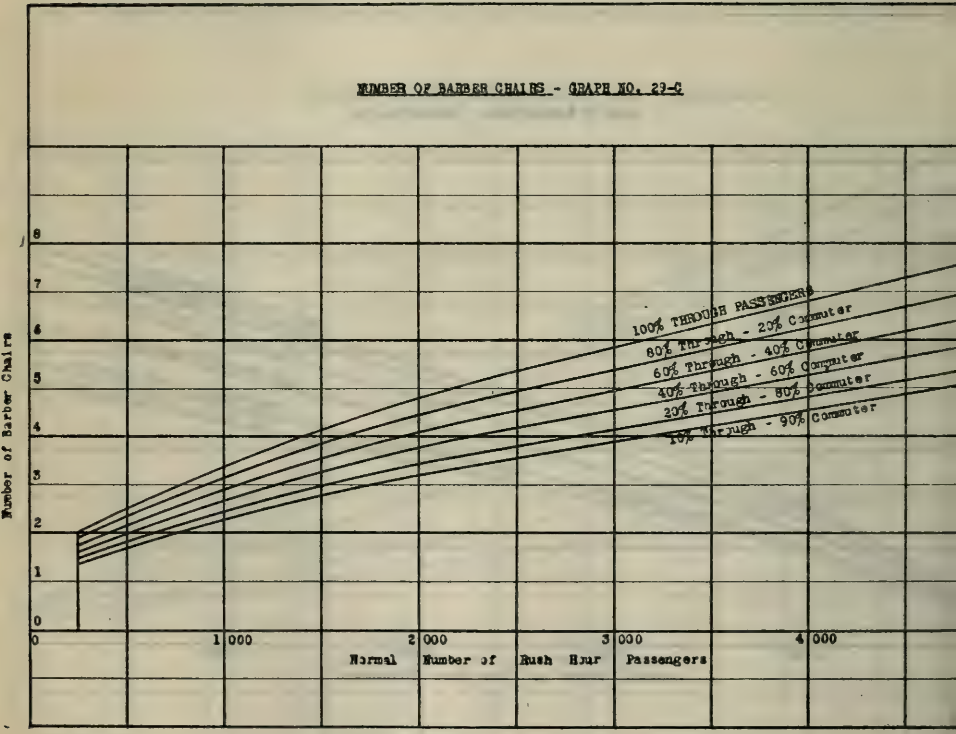


Table 29-A—Number of Barber Chairs

(See Vol. 24, page 862, Table 2; page 924, Table 23; page 926, Graph No. 29)



[3]DESIGN OF COACH YARDS

(1) The coach yard should be placed convenient to the station and mechanical facilities.

(2) The location of a coach yard should be determined by the economic balance between the following factors:

- (a) Available sites.
- (b) Land values.
- (c) Cost of construction.
- (d) Convenience to the station and other facilities.
- (e) Cost of moving equipment between station, coach yard and engine house.

(3) The capacity required in a coach yard depends upon:

- (a) Number of cars and trains to be handled.
- (b) Class of equipment.
- (c) Standard of maintenance.
- (d) Length of layover.
- (e) Frequency of cleaning.

(4) It is common practice to hold trains for cleaning and waiting for less than 24 hours on one track.

(5) There are two general types of coach yard layouts: Stub track and through track. There is also an intermediate type made up of through tracks, but operated generally as two systems of stub tracks. Operation is most efficient in a system of through tracks.

(6) Tracks of equal length and equal to the length of the longest trains give greatest operating efficiency.

(7) A spacing of eighteen feet between track centers has proven ample. Where land values are high, spacing may be reduced to 16 feet or to alternate spacing of 14 and 16 feet.

(8) Tracks should be arranged in groups at the leads to facilitate switching. Auxiliary leads and tail tracks of ample length should be provided.

(9) Nothing sharper than a No. 8 turnout should be used.

(10) The gradient of coach yard tracks preferably should be level, but in no event should it exceed three-tenths per cent.

(11) A wye or loop track should be provided for turning equipment. A loop track is more efficient but requires more space.

(12) Special tracks for making-up or breaking-up trains are sometimes required.

(13) Only light or running repairs are made in a coach yard.

(14) The track-bed and platform-bed in coach yards should be well drained.

(15) Platforms should be placed between all tracks.

(16) The platform should be even in height with the top of rail. The edge of the platform should be five feet six inches from the center of the track. The platform should be crowned $\frac{1}{16}$ inch to the foot.

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[3] Adopted, Vol. 30, 1929, pp. 393, 1396.

(17) Water hydrants should be placed a minimum distance apart equivalent to the average length of cars. Usual practice is to place these in alternate spaces between tracks. However, there is substantial advantage in locating them between all tracks.

(18) Hot water is usually provided in tubs at convenient locations.

(19) Air connections for cleaning should be spaced the same as cold water hydrants; for testing air brakes, connections should be provided through a double connection at the center of each track or through single connections at each end of each track.

(20) Electrical supply connections should be spaced the same as water hydrants, but a minimum distance apart equivalent to twice the average length of cars.

(21) Steam supply connections should be provided in the same manner as air connections for testing air brakes.

(22) A service building and storehouse should be provided.

(23) At least one drop pit, serving two tracks, should be provided in large yards.

(24) Provision should be made to store a sufficient number of car wheels.

(25) There should be a building providing space for the necessary shop facilities.

(26) Refuse disposal, fire protection and flood lighting should be provided.

[4]POINTS TO BE CONSIDERED IN DEVELOPING JOINT PASSENGER TERMINAL PROJECTS

(1) A Consolidated Passenger Terminal for the joint use of two or more railways is assumed to include all the facilities for the passenger station proper; for mail and express service; for the track and street approaches and such other auxiliary or accessory features as may be included within a prescribed boundary or terminal zone; and, preferably, an engine terminal, coach yard, and switching service as well.

(2) Studies for such a terminal should be made by a committee, representing all the parties at interest, composed of engineering, transportation, mechanical, signal and traffic officers.

Preferably the officer whom it is expected will be placed in charge of the property after the consolidation is effected should be made a member of that committee.

(3) A large passenger terminal project affects the community as well as the railway and requires, generally, new legislation and substantial changes in the layout of the adjacent portion of the city itself. It should be so planned, so arranged, so designed, and so developed, as to coordinate with other civic activities. As a rule the railways entering into a terminal project are obliged to make sacrifices—in location, in arrangement, in property retired; and in other ways, in order to meet requirements outside of their own needs. Frequently it is found desirable to make general civic improvements at the same time the terminal work is under way, which

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[4] Adopted, Vol. 28, 1927, pp. 578, 1408.

improvements are primarily for the benefit of the community and not for the railroads. Modification of street approaches is always involved. Each case offers a separate problem but, as a matter of principle, the costs should be assumed by the parties benefited. A method of apportioning the cost of extraordinary or appurtenant work, necessitated by requirements of the nature indicated, should be worked out by experts employed by the committee, submitted to the committee, and developed into a formal agreement with the civic body or bodies having jurisdiction over the matter. All this will require close cooperation between the Terminal Committee, the Planning Board of the city, Executive officers of the city, and perhaps Chambers of Commerce or similar civic groups.

(4) Men having expert knowledge of the various phases and requirements should be employed, as may be commensurate with the magnitude and importance of the task; to be under the direction of, and to make definite reports and recommendations to, the committee; to study the needs of the individual properties and the results to be expected from the combined use of one terminal.

These experts should make investigations by personal inspection of terminal situations somewhat similar to the one under consideration; talk with the responsible officer of similar terminals; examine the facilities provided; see how they function; obtain comments from the men handling the terminals visited; get their suggestions as to improvements which experience has taught them might be made to advantage; study other terminal contracts; accumulate and study reports that have been written covering particular properties, together with the books and articles that have been written upon the general subject; and seek information from all available sources.

(5) The committee should study the possibilities of using the station tracks for auxiliary service when not in use for their normal purpose, as has been done with success in certain cases. For example, station tracks may be used as interchange tracks for freight during any period (say from midnight to morning) when they may be needed only to a limited extent, or not at all, for passenger service.

(6) Preservation of existing railway routes and of existing facilities is desirable from the standpoint of initial expense, but may be extravagant from the standpoint of operating costs and service efficiency. Careful study should be made to strike a true balance between the two, so that the ultimate of efficiency and economy may be reached; keeping in mind the likelihood of the future growth of business, both in total amount, in periodic intensity, in direction, and in character.

(7) Lines for ingress and egress of trains outside of the terminal limits should receive careful analysis to see that they are sufficient for present needs and future growth and are and will continue to be free from congestion; the crossing of train movements at grade should be avoided.

(8) Any necessary freight or industry connections on the station approaches or on lines within or adjacent to the terminal zone, should be considered carefully with a view to avoiding or minimizing interference with passenger service.

(9) Street approaches should receive particular attention and care be exercised to see that they are sufficient in number and width; convenient;

so located and designed as to lead from or around, and not directly into, lines of traffic congestion; that foot passengers and vehicular traffic have their own independent lines of travel without the necessity for crossing each other at grade; that ample accommodation for vehicles handling baggage, mail and express be provided at points which will not interfere with the free movement of taxicabs, motor buses, street cars, private conveyances, or foot passengers.

(10) It may be desirable, and an effective and efficient arrangement as well, to provide subways for foot passengers to cross to the opposite sidewalks of surrounding streets. If provision be not made for this at the outset, pipes, conduits, sewers, etc., may make it difficult, expensive and perhaps impossible, as a practical matter, to take care of the situation later.

(11) Ample provision should be made for convenient access to taxi service within or adjacent to the station. Also for convenient access to street cars, elevated, or underground railways, buses, and other local transportation systems. As far as reasonable, such means of access should be under cover, for protection of passengers from the weather.

(12) The site for the terminal should have a balanced maximum composed of the following characteristics:

- (a) Accessibility—having due regard to modern methods of transportation, land values, and economic requirements.
- (b) Sufficient size and suitable shape to provide for a proper number and length of tracks, and to provide for future growth of both.
- (c) Ease of approach from all the associated rail lines, without excessive curvature or gradient, and without grade crossings.
- (d) Preferably open-air rail approaches, unless all lines are to be electrified.
- (e) Possibilities of proper highway approach development without excessive cost.
- (f) Proper relation, present and prospective, to rapid transit and surface car lines, etc.
- (g) Room for proper by-pass tracks and for the spread of ladder tracks, to provide for free movement and to prevent a tieup of the yard from derailment at the throat, as happens when a "double diamond" layout is used.
- (h) Room for auxiliary facilities conveniently located, such as:
  - (1) Baggage, mail and express.
  - (2) Parking space for Pullman sleepers and private cars.
  - (3) Engine terminal.
  - (4) Coach yard.

(13) In planning the terminal, liberal space should be provided for concessions in the station proper and also in other available parts of the terminal property.

(14) In many cases it may be a direct advantage to provide upper floors with rental space for general office purposes. Access to such offices should be provided separate from the entrances to the station facilities and railway offices.

(15) Frequently economies can be made by concentrating engine facilities and coach yards under the terminal project, and better service rendered. Property of similar character released on individual lines can often be used to advantage in connection with freight service. Sometimes an old coach

yard displaced by the consolidation makes an excellent and much-needed bulk delivery yard. Frequently engine facilities supplanted are needed to take care of freight equipment. Often vacated property can be sold to advantage and at a price that goes far to recoup the owning carrier for its portion of the cost of the new joint facility. Often dead mileage is saved. A loop track can be provided for serving the coach yard and for turning trains.

A modern, substantial plant under one management can be operated at smaller expense and with more regularity than can a number of small plants of the same aggregate capacity, rendering an equal service.

(16) Property taken from a participating railway company for terminal purposes should be purchased by the Terminal Company and compensation made or credit given to the owning company based on a valuation of all the property involved, in due proportion to that paid for similar property acquired from private owners.

(17) A large joint passenger terminal is subject to vicissitudes of weather; to delays and derailments to trains; to late connections; to power failures; to surges in traffic; to bad order equipment; to special trains or cars requiring special handling; to excursion travel; to jubilees, conventions and special functions at irregular periods. The multitude of incidents and accidents that occur make it imperative that someone in authority be present to make quick decision in emergencies and so cover the upset to the regular routine.

(18) A single operating organization should control all activities within the terminal zone. Divided authority means divided responsibility and makes for lack of coordination and consequent confusion, expense, and delay. All employees, when functioning within the terminal, should be under the discipline and control of the terminal officers.

(19) Commensurate authority should go with responsibility and responsibility with authority.

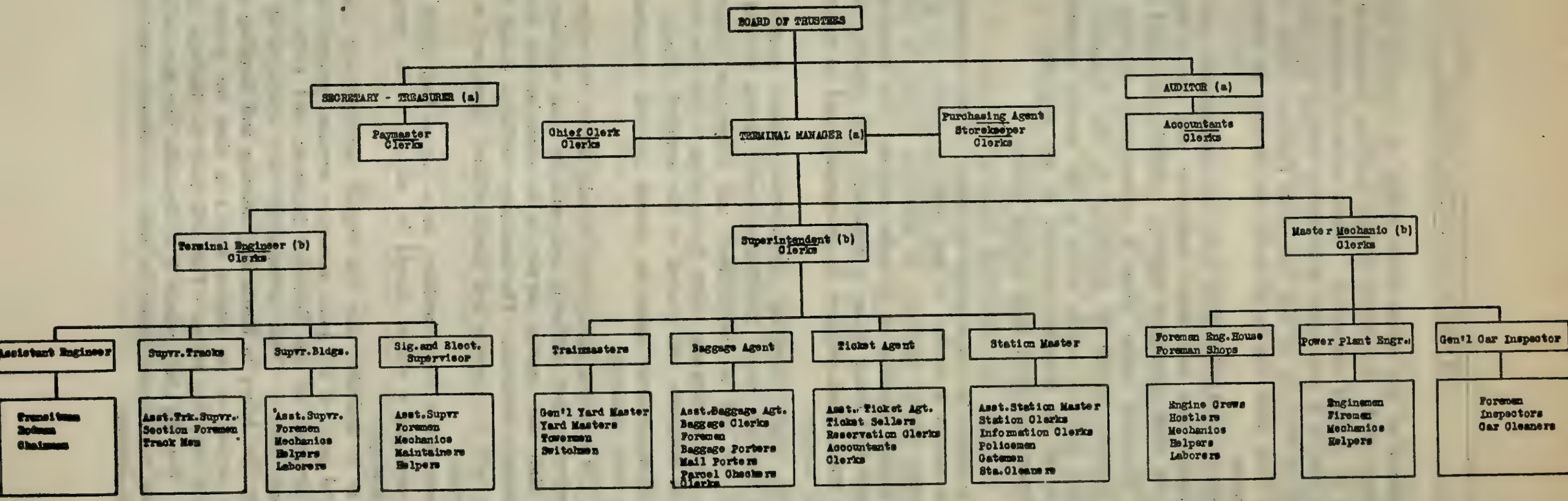
(20) The terminal management should control the maintenance of the property under its own authority and with its own organization.

(21) Mail and express service is an essential and integral part of a joint passenger terminal. The necessary facilities should be planned in cooperation with the express and postal officials concerned in the handling of this service.

The operation of these facilities, in so far as they affect the operation of the terminal as a whole, should be subject to the regulation of the Terminal Manager.

(22) It is desirable that the engine facilities and coach yards be made integral parts of the joint passenger terminal project; to be operated under the direction of the Terminal Manager, and to be subject to his authority and control. This arrangement will eliminate all doubt as to responsibility for delays in hostlering, cleaning and handling of equipment, and for its arrival on the station tracks in time for proper loading and dispatching in outgoing trains. This will tend to eliminate delays in such movements. For the same reason it is desirable that the switching engines and switching movements should be under the direction and control of the terminal organization.

Tentative Operating Organization for a Joint Passenger Terminal Company



[5]FREIGHT TERMINALS

DEFINITIONS

Assisting Gradient.—The inclination given to tracks of a yard to facilitate the movement of cars.

Incline.—An inclined track or tracks and their supporting structure leading to the adjustable apron or bridge at a transfer slip.

Terminal.—An assemblage of facilities provided by a railway at a terminus, or at intermediate points on its line, for the purpose of receiving, sorting, classifying, assembling and dispatching trains.

—Freight.—A terminal provided for handling freight traffic.

—Passenger.—A terminal provided for handling passenger traffic.

—Rail and Water.—A terminal where traffic is transferred between railway cars and boats.

Track.—Ties, rails and fastenings with all parts in their proper relative positions.

—Bad Order.—A track on which bad order cars are placed either for light running repairs or for subsequent movement to repair tracks.

—Body.—Each of the parallel tracks of a yard upon which cars are switched or stored.

—Caboose.—A track on which cabooses are held in a yard.

—Capacity.—The number of cars that can stand on that track in the clear.

—Classification.—One of the body tracks in a classification yard, or a track used for classification purposes.

—Crossover.—A track connecting two adjacent tracks.

—Departure.—One of the body tracks in a departure yard, or a track used for departure purposes.

—Drill.—A track connecting with the ladder track and used for movements in yard switching.

—Hold.—One of the body tracks in a hold yard or a track used for hold purposes.

—House.—A track alongside of, or entering a freight house, and used for cars receiving or delivering freight at the house.

—Icing.—A track on which cars are placed for icing.

—Industrial.—A track serving one or more industries.

—Interchange.—A track on which cars are delivered or received, as between railways.

—Ladder.—A track connecting successively the body tracks of a yard.

—Lead.—An extended track connecting either end of a yard with the main track.

—Passing.—A track auxiliary to the main track for meeting or passing trains, limited to the distance between two adjacent telegraph stations.

—Receiving.—One of the body tracks in a receiving yard or a track used for receiving trains.

—Repair.—A track on which cars are placed for repairs.

—Rider.—A track in a hump yard on which a conveyance is operated for returning car riders to the summit of the hump.

—Running.—A track reserved for movement through a yard.

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[5] Adopted, Vol. 28, pp. 616, 1410.

TRACK—Continued

—SCALE.—A track leading to and from and passing over a track scale.

—SIDE.—A track auxiliary to the main track for purposes other than for meeting and passing trains.

—SORTING.—One of the body tracks in a sorting yard or a track used for sorting purposes.

—SPUR.—A stub track diverging from a main or other track.

—STORAGE.—One of the body tracks in a storage yard or a track used for storage purposes.

—STUB.—A track connected with another one at one end only.

—TEAM.—A track on which freight is transferred directly between cars and highway vehicles.

—TRANSFER.—A track so located with respect to other tracks and to transferring facilities as to facilitate the transfer of lading from one car to another.

—WYE.—A triangular arrangement of tracks used for turning engines, cars or trains.

TRANSFER SLIP.—A protected landing place for transfer boats with adjustable apron or bridge for connecting tracks on the land with those on the transfer boats.

YARD.—A system of tracks within defined limits provided for making up trains, storing cars, and other purposes, over which movements not authorized by time table or by train-order may be made, subject to prescribed signals, rules and regulations.

—CAPACITY—STANDING.—The sum of the capacities of all the tracks in that yard on which cars may be permitted to stand.

— — WORKING.—The maximum number of cars that can be regularly dispatched from that yard in 24 hour periods.

—CLASSIFICATION.—A yard in which cars are classified or grouped in accordance with requirements.

—DEPARTURE.—A yard in which cars are assembled in trains for forwarding.

—FLAT.—A yard in which the movement of cars is accomplished by a locomotive without material assistance by gravity.

— — DOUBLE.—A flat yard designed as two adjacent or separate units, each unit to handle traffic in a single direction opposite to that of the traffic handled in the other unit.

— — SINGLE.—A flat yard designed as a single unit to handle traffic in both directions.

—GRAVITY.—A yard in which the classification of cars is accomplished by gravity.

—HOLD.—A relief yard for holding cars or trains convenient for immediate use.

—HUMP.—A yard in which the classification of cars is accomplished by pushing them over a summit, beyond which they run by gravity.

—POLING.—A yard in which the movement of cars is accomplished by the use of a pole operated by an engine on an adjacent parallel track.

—RECEIVING.—A yard for receiving trains.

—SORTING.—A yard in which cars are classified in greater detail after having passed through a classification yard.

—STORAGE.—A yard in which cars are held awaiting disposition.

[c]FREIGHT YARDS

General

(1) Freight yards are essentially supplementary units and should be so designed and operated in relation to each other and to the lines tributary to them as to give the most economical results for the railway as a whole.

(2) The number of yards should be as small as is consistent with the efficient handling of traffic.

(3) An existing yard which is inadequate to handle the existing or immediately prospective traffic should be enlarged, or redesigned and rebuilt, or abandoned in favor of a yard in a different location, according to which of these alternatives will result in the greatest economy.

(4) An additional yard is warranted only when it will result in greater economy than enlargement or reconstruction of, or substitution of a new yard for an existing yard or yards.

(5) The type of yard which should be adopted in any given case depends upon the traffic to be handled through it.

(a) A single flat yard is adapted for handling traffic where the total number of cars is small and the number of switching cuts per train is also small.

(b) A double flat yard is adapted for handling traffic where the total number of cars is large but the number of switching cuts per train is small.

(c) A gravity yard or a hump yard is adapted for handling traffic where the total number of cars is large and the number of switching cuts per train is also large—also in special cases where the total number of cars is relatively small but normally received in a short period of time, and the number of switching cuts per train is large and must be made promptly so as to pass the cars through the yard in a limited time.

(6) Future expansion of a yard should be so provided for that the number and length of the tracks in it may be increased as required with a minimum of interference with operation or relocation of existing trackage.

(7) The total standing capacity of the receiving, classification and departure tracks may be roughly assumed to be about equal to the working capacity of the yard.

(8) In computing car capacity 45 feet per car should be allowed for all freight car tracks other than repair tracks, for which 55 feet per car should be allowed, in order to provide room for working around the ends of cars.

(9) Main tracks should not pass through a yard.

(10) The locomotive terminal should be so located that the aggregate mileage run by all locomotives in moving between it and the various points in the yard, or between it and the main track, will be a minimum, and that it will be easy of access from both the yard and the main track with a minimum of reverse or conflicting movements.

(11) Facilities in the locomotive terminal should be arranged to permit of the most direct and rapid handling of locomotives.

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[c] Adopted, Vol. 28, pp. 621, 1412; Vol. 29, 1928, pp. 432, 1339.

(12) Yard lighting by individual lamps may be accomplished with 1500-watt nitrogen lamps, spaced 140 to 150 feet apart and hung 28 feet, or more, above the tracks for hump and ladder track lighting, and, for body track lighting, spaced and hung as required to make all cars clearly visible.

(13) Yard lighting by flood light projectors may be accomplished either by lights arranged in groups on towers approximately 85 feet in height, or by distributing these lights through the yard on poles 55 to 70 feet in height, in which case the light beam should be directed parallel to the tracks and in the direction of traffic or diagonally across the tracks against the direction of traffic.

(14) Frogs of greater angle than No. 8 should not be generally used.

(15) The angle between a ladder track and the body tracks should be not less than the angle of the frogs used in the ladder track, and not more than will provide the distance on the ladder track required for the length of turnout used.

(16) Ladder tracks should be spaced not less than 15 feet center to center from any parallel track, and when such parallel track is another ladder track, they should be spaced not less than 18 feet center to center.

(17) Body tracks should be spaced not less than 13 feet center to center, and when parallel to a main track or important running track, the first body track should be spaced not less than 15 feet center to center from such track.

Receiving Tracks

(18) The number of receiving tracks should be such that there will be one available whenever an arriving train offers to enter the yard.

(19) The length of receiving tracks should be such that each will accommodate a complete train, including assisting locomotives where used.

(20) The gradient of receiving tracks, if adverse to the forward movement of a train, should be at least 20 per cent less than the ruling gradient encountered by that train during its road trip.

(21) In a hump yard the gradient of the receiving tracks and the tracks leading to the summit of the hump should be such that one locomotive can push the maximum train over the hump at the required speed.

(22) Compressed air at suitable pressure should be piped along the receiving tracks and provided with sufficient outlets to permit of testing the air brake equipment on the cars of all arriving trains.

Classification Tracks

(23) The number of classification tracks should be such that there will be at least one available for each classification to be made in the yard.

(24) The length of classification tracks should be such that each will normally hold all accumulated cars of the assigned classification until they are to be moved off the classification track under normal operation.

(25) In a hump yard where cars of single classifications accumulate rapidly enough to permit of forwarding them in whole trains, the classification tracks may be used as departure tracks with their lengths determined accordingly.

(26) Sorting of cars in a hump yard by flat switching at the lower end of the classification tracks should be avoided.

(27) Considerable sorting of cars in a hump yard is an indication of an insufficient number of classification tracks, and when this disability cannot be overcome, the mixed cuts may be reclassified over the hump.

Sorting Tracks

(28) The location of the sorting yard should be such that mixed cuts may be moved from the classification yard, sorted, and moved directly to the departure yard without interfering with the operation of the main hump.

(29) A flat sorting yard is required when the amount of sorting to be done is too great to be handled on the departure tracks, and when the amount of business will not permit of re-humping mixed cuts.

(30) A hump sorting yard may be required when the amount of sorting to be done is greater than can economically be handled in a flat sorting yard.

(31) The number and length of sorting tracks depends upon the amount of sorting and the number of secondary classifications, and may be determined in the same manner as the number and length of classification tracks.

Departure Tracks

(32) The number of departure tracks should be such that there will be one available for assembling a departing train whenever necessary.

(33) The length of departure tracks should be such that each will accommodate a complete train including assisting locomotives where used.

(34) The gradient of departure tracks, if adverse to the forward movement of a train, should be at least 20 per cent less than the ruling gradient to be encountered by that train during its road trip.

(35) In a hump yard where cars of single classification accumulate rapidly enough to permit of forwarding them in whole trains, the classification tracks may be used as departure tracks, with their lengths determined accordingly, until such time as departure tracks must be provided to hold accumulated trains and thus afford relief for the classification tracks; but where cars of single classifications do not accumulate rapidly enough to permit of forwarding them in whole trains, and each train must normally be made up of a number of different classifications, separate departure tracks should be provided to permit of building short classification tracks and to facilitate assembling different classifications into a single train.

(36) Sorting of cars in a hump yard may be economically accomplished by flat switching on the departure tracks, but departure tracks should not be installed primarily for this purpose.

(37) Compressed air at suitable pressure should be piped along the departure tracks and provided with sufficient outlets to permit of testing the air brake equipment on the cars of all departing trains.

Repair Tracks

(38) The location of repair tracks should be such that the connection from the bad order tracks will be as direct and as simple in alinement as practicable, that switching the repair tracks will not interfere with other work going on in the yard, and that repaired cars may readily be returned to the receiving, classification or departure tracks as required.

(39) The capacity of the individual repair tracks should not exceed a maximum of 15 cars each and in computing this capacity 55 feet should be allowed for each car.

(40) The spacing of repair tracks should be alternately 16 feet and 24 feet center to center, and they should preferably be connected at both ends.

(41) A material supply track should be placed between the repair tracks which are spaced 24 feet center to center.

Miscellaneous Tracks

(42) Bad order tracks should be provided as required to accommodate the bad order classification and should be so located as to be convenient of access both for setting out bad-order cars and for moving these cars to the repair tracks.

(43) Caboose tracks should be so located that cabooses can be placed on and removed from them in the order of their arrival, and should preferably be so constructed that cabooses can be dropped by gravity on to the rear of trains made up for departure.

(44) Connections to the main track from the receiving or departure tracks should be as direct and as simple in alinement as practicable.

(45) Crossover tracks should be provided as required to facilitate all normal and regular movements in the yard or between the yard and the main track, and their location should be such as to cause a minimum of interference between different movements which it may be desirable to make simultaneously.

(46) Drill tracks should be so located that movements on them will cause a minimum of interference with other work being done in the yard and with road trains pulling into or out of the yard, and that an engineman working on the drill track will have a clear view of the switchmen working along the ladder track.

(47) Icing tracks should be so located as to permit of icing cars as required in a minimum of time.

(48) Lead tracks somewhat longer than a maximum train length, or freight main tracks extending to or beyond the first telegraph office outside of the yard, in either or both directions, should be provided as required.

(49) Running tracks should be provided as required to permit free movement from one position in the yard to another and between the yard and the locomotive terminal, with a minimum of interference with other work being done in the yard.

(50) Scale tracks should be so located that before cars are classified they may be weighed with a minimum of movement and delay, and where the number of cars to be weighed may exceed 30 in one hour, should be located on gradients such as to permit weighing of cars in motion; a track parallel to the scale track should be provided for non-weigh traffic.

Hump Yards With Car Riders

(51) A rider track should be provided through the center of the classification yard independent of other yard tracks, so arranged and operated as to reduce the hazard of personal injury to car riders and to minimize the number required by facilitating their prompt return to the hump.

(52) The gradients from the summit of the hump should be such that cars will run by gravity to the far end of each classification track and the steepest of these gradients should be immediately following the summit of the hump.

(53) A hump may be raised temporarily in the winter when conditions require.

(54) Tracks for empty classifications should be so located in the classification yard and the gradients leading to them should be such that empty cars moving to them will not be overtaken by loaded cars.

(55) A cut list prepared in multiple by the yard clerk for each arriving train on the form shown below, giving the number of the cut in the order in which it will pass over the hump, the number of the track in the classification yard to which the cut is destined, and the number of cars in the cut, with a copy of this list supplied to each car cutter, towerman, and switchtender who is concerned in handling the cuts shown on the list, is an efficient aid to the handling of cars.

(56) The cut list may also be made a permanent record of car rider performance to assist in fixing responsibility in the case of loss or damage to freight.

Cut List

No. of Cut	No. of Track	Cars In Cu
1		
2		
3		
4		
5		

Cut List

No. of Track	Cars In Cut

Cut List

No. of Track	Cars In Cut

Cut List

No. of Track	Cars In Cut

Terminal Times and Delays

In order to minimize the time that the road train crew and locomotive crew need be on duty in their initial and final terminal yards when these are large yards:

(57) The duties to be performed by these crews in the yard should be made as simple and easy to accomplish as practicable.

(58) The dispatcher should give the yardmaster advance notice of the probable arriving time, length, and amount of work to be done on each train so that he may be prepared to handle it promptly.

(59) The departure time of each train should be fixed to the mutual satisfaction of the yardmaster and the dispatcher, and each train should have all necessary orders and be ready to depart on time.

(60) The train crew should sign on duty where the conductor receives train orders, way bills, and the train list, if this is prepared by yard forces, and this should be convenient to the departure end of the departure tracks.

(61) The locomotive crew should sign on duty convenient to the point at which they take charge of the locomotive.

(62) The train crew should sign off duty where the conductor delivers the train list, way bills and report of bad-order cars, and this should be convenient to the receiving end of the receiving tracks.

(63) The locomotive crew should sign off duty where the engineman delivers the work list and this should be convenient to the place where the final inspection of the locomotive is made.

(64) Yard forces should test air brake equipment of cars on the receiving tracks after the road locomotive has departed from, and on the departure tracks before the road locomotive has arrived on those tracks, leaving the final make up fully charged with air.

(65) Yard forces should switch all bad order cars and cars for which no way bills are available out of the make up for a train, before the road locomotive arrives on the departure tracks.

(66) Locomotive terminal forces should move the locomotive into and out of the engine house, furnish it with coal, water and other supplies, and clean the fire and ash pan.

(67) Adequate inspection space and facilities should be provided for making the final locomotive inspection after arrival at and the initial locomotive inspection before departure from the locomotive terminal.

(68) Switch tenders or interlocking plants should handle all switches to be run over by the locomotive in moving to and from the locomotive terminal and by the train in moving to and from the main track when this can be shown to be economical.

(69) Train supplies should be placed on the caboose by either the train crew or yard forces as may be found the more economical, and should be obtainable from a place so located as to facilitate placing them on the caboose.

(70) Additional or improved facilities for the purpose of reducing terminal times and delays are justified when, all other things being equal, the total additional cost of operating, maintenance, and fixed charges on them will be less than the cost of the terminal times and delays which they will eliminate.

TRANSFER OF LADING OF BAD-ORDER CARS

(71) A locomotive crane is usually economical for use in transferring freight between open top cars when the manual labor otherwise required is the equivalent of the constant daily service of six men; and the intermittent use of a locomotive crane, when the machine may be economically employed at other times, is usually justified when it replaces similar intermittent service of six men.

FREIGHT TRANSFER STATIONS

(72) A freight transfer station should be provided where it is desired to consolidate L.C.L. freight from a greater into a lesser number of cars, or to separate it from a lesser into a greater number of cars, or where it is desired to transfer package freight from foreign line cars into home line cars for forwarding to destination.

(73) The transfer platform, for hand trucking, should be not more than 24 feet wide, should be covered, and should have a pair of tracks on each side of it.

TEAM YARDS

(74) The location of a team yard should be such that it will be convenient for use by shippers and consignees, and also as convenient as pos-

sible to a freight house so that the receipt and shipment of freight may be easily under control of the freight agent's force.

(75) Team yard driveways should be paved and maintained in good condition.

(76) A crane for handling heavy freight should be provided when required.

(77) A motor truck scale, with office, should be provided near the main entrance to the team yard when required.

(78) Switching tracks for holding and working cars should be provided in the immediate vicinity of the team tracks and so arranged as to facilitate the switching of these tracks.

WIDTH OF DRIVEWAYS FOR TEAM TRACKS AND FREIGHT HOUSES

(79) Team-track driveways normally should be of a sufficient width to allow the longest trucks using the driveway to stand at right angles to the car, with sufficient space remaining in front of the truck to allow another truck of maximum width to pass.

(80) Team-track driveways of sufficient width to enable two maximum-size trucks to load opposite each other at right angles to the cars, and with a clear passageway between them for the passing of a maximum-width truck, are not justified economically except in special cases where an extremely intensive truck traffic is handled.

(81) There probably will not be any further tendency to increase the maximum size of trucks now being operated in team-track and freight-house service. The maximum overall size of truck recommended for determining team-track and freight-house driveway widths is 8 x 27 ft.

(82) Outside of heavy machinery, heavy rolls of paper, and similar shipments, practically all commodities handled on team tracks are adapted to side loading of trucks.

(83) At present only about ten per cent of the trucks used in team-track service are adapted to side loading.

(84) It is not advisable at the present time to recommend generally a width of team track based on exclusive side loading of trucks, though the economic advantages of this method of loading from the railroad's standpoint are obvious. Truck manufacturers should be encouraged in the building of trucks adapted to side loading.

(85) The following clear width of team-track driveways are recommended for the various conditions indicated:

(A) Where side loading of trucks is employed exclusively:
    For driveway alongside one track............20 ft.
    For driveway between two tracks............30 ft.
(B) Where side loading of trucks is not universally followed:
  Normal conditions,
    For driveway alongside one track............37 ft.
    For driveway between two tracks............40 ft.
    For backing-up space alongside a public thoroughfare .... 27 ft.
  Where land value is high,
    For driveway between two tracks............35 ft.

(86) The distance between track centers where the driveway is located between tracks, should be ten feet greater than the width of the driveway.

(87) The spacing of tracks, where multiple team tracks are built, may be fixed by regulatory bodies, but it is recommended that the maximum distance between track centers be 13 ft.

(88) Stub-ended driveways serving team tracks should be avoided. Where team tracks are more than 20 cars long (per single track), intermediate connecting cross drives should be provided. In large team-track developments where exceptionally long tracks are provided, cross drives should be introduced so that 14 cars per track is the maximum length between any two drives.

(89) The maximum width of a freight-house driveway should be sufficient to provide for trucks backed up to the freight house at right angles and to leave room in front of the truck for two trucks to pass.

(90) Freight-house driveways should be of the following maximum widths for the various conditions indicated:

(A) With tailboard on one side....................47 ft.
(B) With tailboard on both sides....................70 ft.
(C) Free back-up space alongside a public street...27 ft.

FREIGHT HOUSES

General

(91) The ultimate size of a freight house should be determined in advance from consideration of the average amount of traffic to be handled through it in the first instance, the variation of peak from average requirements, and the probable growth of requirements during the period in which the cost of the structure can be amortized.

(92) The initial size should be determined by immediate future needs with provision for increases to the ultimate size as required.

(93) Minimum operating costs can be attained in freight houses of great capacity by locating the house tracks between two houses connected at the bumper end of the tracks by a platform.

(94) Combination inbound and outbound freight houses should be arranged with the house tracks between them, and be connected at the bumper end of the tracks by a platform.

(95) The factors of design for a freight house such as tailboard frontage, floor area, width of house, platforms, bridges and roadways, and the capacity of elevators should be so correlated that no one factor will limit the capacity of the house.

House Tracks

(96) The capacity of the inbound house tracks should be such that not more than one change in the inbound setting of cars need be made during the daily period of freight house operation, and that this change may be made during the noon hour.

(97) The capacity of the outbound house tracks should be such that the outbound setting of cars may be left undisturbed during the daily period of freight house operation.

(98) Spotting cars at freight houses to permit of trucking through them is common practice, and the cost of spotting and recoupling, exclusive of all other switching, based on a switch engine and crew cost of $12.50 per hour, amounts to approximately 28 cents per car.

(99) Spotting may be eliminated by providing a platform and continuous doors on the track side of the freight house, constructing platforms between each pair of house tracks, and connecting them to the freight house by a platform at the bumper end of the tracks, and, when the length of the setting is sufficient to warrant, by the installation of trucking bridges at intervals through the setting.

(100) Spotting is more economical than intermediate platforms when land values exceed $6 per sq. ft.

General Dimensions of Freight House

(101) Tailboard frontage has an average capacity of approximately 1.12 tons per linear foot per day, and may determine the minimum length of freight house required.

(102) The gross floor area of an inbound house should be provided at the rate of approximately 130 sq. ft. per ton of daily capacity of the house.

(103) The width of an outbound house where tractor trucking is to be used, should be from 50 to 60 feet.

(104) The shortest length consistent with adequate tailboard frontage is the most economical for both inbound and outbound freight houses.

Trucking and Stowing

(105) The cost of tractor trucking in the freight house in dollars per ton, on the basis of an average rate of pay for labor of 51 cents per hour, can be determined approximately by the equation $C = .14 + .0183d$ in which d represents the average distance in hundred feet that freight is trucked.

(106) The cost of hand trucking in the freight house in dollars per ton, on the basis of an average rate of pay for labor of 48 cents per hour, can be determined approximately by the equation $C = .13 + .06d$ in which d represents the average distance in hundred feet that freight is trucked.

(107) The average trucking distance in an outbound house where freight is received uniformly along one side and distributed uniformly along the other side, is theoretically one-third the length of the house, but in practice it approximates three-tenths the length of the house.

(108) Tractor trucking is more economical than hand trucking when the length of the house and tonnage handled is sufficient to warrant its use.

(109) The cost of stowing, which also includes the cost of trucking the freight from the freight house or platform through the cars, in dollars per ton, on the basis of an average rate of pay of labor of 52 cents per hour can be determined approximately by the equation $C = .12 + .0367N$, in which N represents the average number of cars in each run through which freight is trucked for stowing.

(110) Supervision of stowing should be in the hands of specially assigned men who should be held responsible for proper stowing in the cars assigned to them.

Freight Elevators

(111) The modern freight elevator is the only practical means developed to date and generally accepted in freight houses for the vertical transportation of freight.

(112) Elevator control may be either automatic or manual, but most new installations are of the push-button automatic type.

(113) The number of elevators in a two-level outbound freight house (where the major longitudinal trucking is done by tractors on one level, and the minor trucking, i. e., from wagon to nearest elevator, or from nearest elevator to cars, is done by hand trucking on the other level) if they are uniformly spaced, has practically no influence on the average length of tractor trucking, but does influence the average length of hand trucking and the capacity of the house.

(114) The distance between elevators which will theoretically result in minimum trucking and elevating cost in a two-level freight house operated as in item 113 is represented by the equation,

$$g=\sqrt{\frac{(Pr+E)\,L}{.015T}}$$

in which g represents distance between elevators in hundred feet; P represents the first cost of one elevator; r represents the annual interest rate; E represents the annual cost of one elevator operator; L represents the length of house in hundred feet; and T represents the total yearly tonnage.

Two-Level Freight Houses

(115) A two-level freight house occupies less land area per ton of capacity than a one-level freight house, but the cost of construction is greater, and the building cannot be altered as readily to meet changing conditions.

(116) Differences in elevation between track and street level, due to topography or grade separation, may indicate the advisability of a two-level freight house in order to eliminate teamway ramps.

(117) Grade separation of tracks and highways may be secured in a two-level freight house so that there is no interference between teaming and switching movements, and so that with trucking on the track level, the length of car settings is not limited to the distance between streets.

(118) Trucking costs in a properly designed two-level freight house are less than in a one-level freight house of the same capacity, but this is somewhat offset by the cost of elevating freight.

(119) Stowing costs will be less in a two-level outbound freight house than in a one-level outbound freight house if the loading platform is located in the middle of the outbound setting of cars.

(120) A combination inbound and outbound freight house of the two-level type is more economical than separate inbound and outbound freight houses of this type.

(121) A two-level freight house is more economical than a one-level freight house when land values exceed twenty dollars per square foot, but the development of air rights above the freight terminal for other than railway purposes may in such cases warrant a one-level installation.

(122) A multiple-level inbound freight house may prove an economical method of securing additional storage space for freight.

[7]RELATIONS BETWEEN FACTORS OF DESIGN IN WAREHOUSES

(123) One elevator should be provided for each 40,000 sq. ft. of warehouse space served.

(124) The shipping platform area should be 4 per cent of warehouse storage floor area.

(125) There should be one car length of track siding for each 17,600 sq. ft. of warehouse storage area.

(126) There should be one foot of tailboard frontage for every 1100 sq. ft. of warehouse storage area.

(127) There should be 16 feet of tailboard frontage for each car length of siding.

[8]CATECHISM OF YARD DESIGN AND OPERATION

(128) A catechism designed to bring out hints as to the improvement in detail of existing yards, and the elimination of slight difficulties which hinder the steady operation of yard service or cause detensions which are small in themselves but become serious in the aggregate, appears on pages 316 and 1121 of Vol. 19, and also on page 694 of the 1921 Manual.

[9]SCALES

DEFINITIONS

SCALE.—A mechanical device for weighing.

RAILWAY TRACK SCALE.—A scale especially designed for weighing railway equipment.

MASTER TRACK SCALE.—A track scale especially designed for the calibration of railway test weight cars or for other special weighing where extreme accuracy is required.

MOTOR TRUCK SCALE.—A scale especially designed for weighing motor trucks.

BUILT-IN SCALE.—A scale whose lever mechanism is erected upon a pit foundation or equivalent structure built in the field, and whose superstructure, including the weighing platform, is of a character not fabricated in scale manufacturing plants and not generally secured from or through the scale manufacturer.

SELF-CONTAINED SCALE.—A scale in which the lever system is enclosed in a box frame equipped to receive it and provided with platform, all comprising a complete weighing unit furnished by the scale manufacturer for installation in a fixed location.

PORTABLE SCALE.—A scale mounted on wheels or otherwise designed for easy movement from place to place.

Explanatory Note

The Specifications for Four-Section and Two-Section Track Scales were prepared by a committee representing the American Railway Association, the American Railway Engineering Association, the United States

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[7] Adopted, Vol. 23, 1922, pp. 76, 1030.
[8] See Vol. 19, 1918, pp. 316, 1121.
[9] Adopted, Vol. 24, 1923, pp. 816, 1211; Vol. 28, pp. 612, 1409.

Bureau of Standards, the Railroad and Warehouse Commission of Minnesota, the National Scale Men's Association and the Scale Manufacturers' Association. Acknowledgment is made of the value of similar work previously done by railways and organizations from whose specifications preferred sections and items have been selected and co-ordinated to produce a standard which should be acceptable to all interests for general use throughout the United States.

[10]SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF FOUR-SECTION RAILWAY TRACK SCALES

(For Knife-Edge Scales Only, Not Including Overhead Suspension Scales

INTRODUCTION

These specifications are intended to apply to knife-edge scales of the straight and torsion lever types for weighing cars in regular interchange service. They do not apply to overhead suspended scales, nor to scales now in service except that reinstallations of old scales should be governed as nearly as practicable by the provisions of the specifications relating to installation of new scales. They are intended, except in special cases, to secure reasonable uniformity in scales for similar service but without preventing improvements in types of scales or in scale parts.

Requirements not in common with other track scale specifications are the provision for two classes of scales to meet weighing conditions as determined by the volume of traffic to be weighed; and standardization of capacities and lengths as follows:

Heavy Service Scales to have sectional capacities of seventy-five and one hundred tons; and lengths of fifty, fifty-six and sixty feet.

Light Service Scales to have sectional capacities of sixty and seventy-five tons; and lengths of fifty, fifty-six and sixty feet.

Heavy Service Scales and Light Service Scales differ principally in the features which affect wear in use and not at all in strength for given capacities. It is intended that the Heavy Service Scales shall be selected for usual railroad and industry installations. The use of the Light Service Scales is intended for locations where relatively only a few cars are to be weighed.

Requests for proposals for track scales to conform to these specifications should specify the class, sectional capacity and length of scale required, together with such other information as will insure complete and uniform proposals.

Section I—Classes of Scales

1. **Character of Classification.**—Scales shall be divided into two classes, namely, **Heavy Service Scales** and **Light Service Scales**; and except when otherwise specifically provided these specifications are to apply to both classes of scales.

(a) **Heavy Service Scales.**—Heavy Service Scales are those over which a large number of cars are to be weighed; and they shall have sectional capacities of 75 or 100 tons, except for special cases.

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[10]Adopted, Vol. 21, 1920, pp. 855, 1446.

(b) **Light Service Scales.**—Light Service Scales are those over which relatively only a few cars are to be weighed; and they shall have sectional capacities of 60 or 75 tons, except for special cases.

2. **Special Cases.**—For special cases which cannot be covered in these specifications, it is recommended that the material, workmanship, etc., shall be at least equal to that required in these specifications, and that the principles herein set forth be followed in so far as they apply.

SECTION II—CAPACITY

1. **Capacity Defined.**—The capacity of a scale is equal to the weight of the heaviest car it will weigh, provided that the scale will support a train of such cars passing over the scale without stresses being developed in the members of the scale which are in excess of those hereinafter specified. The car weight for a given sectional capacity and given length of scale is shown in table for Scale Capacities and Weigh-Bridge Girders, Section XXIV.

2. **Capacity Required.**—The capacity of the scale shall be sufficient to meet the requirements of the heaviest service to which it may be subjected.

3. **Sectional Capacity.**—The sectional capacity of the scale is the greatest weight which, if applied on the load knife edges of each pair of main levers, will produce stresses in the scale parts not exceeding those given in the table of Working Stresses, Section IV.

SECTION III—PLANS

1. **Plans.**—The manufacturer shall furnish to the purchaser plans of design showing stresses and detailed dimensions for all scale parts, and the material of which they are to be fabricated; also assembly plans showing location of all field connections and all information necessary for the purchaser to design and construct the pit and parts not furnished by the scale manufacturer.

SECTION IV—WORKING STRESSES

1. The following unit stresses shall not be exceeded when the scale is loaded to its capacity as defined above. These stresses include an allowance for impact caused by moving loads. The strength of each member shall be determined by its weakest cross-section.

2. **Iron and Steel, Working Stresses in Pounds Per Square Inch.**

					Steel for Pivots and Bearings	
Nature of Stress	Cast Iron	Steel Castings	Machinery Steel	Structural Steel	High Carbon	Special Alloy
Tension	1,500	8,000	8,000	10,000	24,000	30,000
Compression	8,000	10,000	8,000	10,000	24,000	30,000
Transverse Bending						
Tension	2,500	8,000	8,000	10,000	24,000	30,000
Compression	8,000	10,000	8,000	10,000	24,000	30,000
Shear	2,500	6,000	5,000	7,000	.....	.....
Torsion	2,500	6,000	.....	7,000	.....	.....

The bearing stress on steel pins shall not exceed 15,000 lb. per square inch.

3. **Knife Edge Bearing Stresses:**

(a) **Heavy Service Scales.**—For Heavy Service Scales the load per linear inch of knife edge shall not exceed 5000 lb. for high carbon steel or 6000 lb. for special alloy steel.

(b) **Light Service Scales.**—For Light Service Scales the load per linear inch of knife edge shall not exceed 6000 lb. for high carbon steel or 7000 lb. for special alloy steel.

4. **Concrete Bearing Stresses.**—Stresses to be allowed for bearing on concrete shall not exceed 300 lb. per square inch under scale lever stands, and at all other points shall not exceed 400 lb. per square inch.

5. **Loops, Formula for Stresses.**—Considering the end of the loop as a simple beam, its section at the point of maximum bending shall be determined by the formula $\frac{W}{4}\left[L-\frac{l}{2}\right]$ wherein W equals the maximum load applied to the loop, L equals the distance between the center lines of the depending sides, and l equals the distance over which the load is distributed.

6. **Projecting Pivots, Formula for Stresses.**—Where practicable, the pivots shall be supported their full length by integral parts of the lever. Where impracticable to so support the pivots, the bending moments shall be determined as follows:

Let W = the total load on both ends of pivot in pounds.
L = the moment arm in inches.
l = the length of bearing in loop, in inches.
T = distance between friction faces of loop, in inches.
B = the width of boss or sustaining member enveloping pivot, in inches.
M = bending moment in pivot, in inch-pounds.

Then:

$$L = \tfrac{1}{2}l + (T - B) + \tfrac{1}{4}\text{ in.}$$

and:

$$M = \frac{WL}{2} = \frac{W}{2}\left[\tfrac{1}{2}l + (T - B) + \tfrac{1}{4}\text{ inch.}\right]$$

SECTION V—LENGTH OF SCALE AND NUMBER OF SECTIONS

1. **Scale Length Defined.**—The length of a scale shall be considered as the effective weighing length of the live rails. In no case shall this effective weighing length be greater than the distance between the centers of end sections.

2. **Scale Lengths Standardized.**—The lengths of scales, except in restricted traffic movements, or for special cases, shall be 50, 56 or 60 feet.

3. **Number of Sections.**—Scales of 60 feet or less in length shall not be constructed in more than four sections.

4. **Motion Weighing.**—When cars are to be weighed in motion the speed shall not exceed four miles per hour and each car shall be entirely and alone on the scale a minimum of four seconds. This condition applies to cars normally weighed. When scales are of such a design or length as not to permit of the above condition, cars shall be spotted to secure accurate weights.

SECTION VI—SCALE LEVERS

1. **Qualities of Castings.**—The finished levers shall not be unduly warped; they shall be free from blisters, large holes or other imperfections, and shall be brought to a reasonably smooth finish.

2. **Machined Ways for Nose Irons.**—Levers that are to be equipped with nose irons shall have those portions of the lever ends receiving them machined for the full distance over which the nose irons are to move.

3. **Leveling Lugs.**—In scales of the straight lever type each lever shall be provided with leveling lugs for longitudinal alinement. In scales of the torsion lever type, leveling lugs shall be provided on the pipe or torsion member for transverse alinement and on the extension arm for longitudinal alinement. Each pair of lugs shall be spaced 11 inches. The leveling surfaces of each pair of lugs shall be finished to a common plane which shall be parallel to the plane established by the knife edges of the end pivots.

4. **Marking of Levers.**—Figures denoting the multiple of each lever shall be cast or otherwise permanently marked in plain figures thereon.

5. **Length, Allowable Variation.**—All main levers shall be true to within ⅛ inch; and all extension levers shall be true to within ¼ inch of their nominal lengths between the knife edges of end pivots.

6. **Loading of Levers Other Than Main Levers.**—In establishing the load for determining the stresses in the levers other than main levers, it shall be assumed that the end extension levers carry a total live and dead load corresponding to 100 per cent of the sectional capacity; the portion of the middle extension levers carrying the load from the end section only, 100 per cent of the sectional capacity; and the portion of the middle extension levers carrying the combined load from the end section and inner section, 160 per cent of the sectional capacity; the transverse extension lever, shelf lever and beam, 300 per cent of the sectional capacity.

Section VII—Pivots and Knife Edges

1. **Material.**—The requirements for physical properties of the steel used for pivots shall be as follows:

(a) **Special Alloy Steel in the Annealed State:**

Elastic Limit	Not over 75,000 lb. per sq. in.
Tensile Strength	Not over 110,000 lb. per sq. in.
Elongation in 2 in.	Not less than 20 per cent.
Reduction in Area	Not less than 35 per cent.

(b) **Special Alloy Steel Hardened:**

Elastic Limit	Not less than 160,000 lb. per sq. in.
Tensile Strength	Not less than 200,000 lb. per sq. in.
Elongation in 2 in.	Not less than 5 per cent.
Reduction in Area	Not less than 25 per cent.
Shore Hardness	Not less than 85.

(c) **High Carbon Steel in the Annealed State:**

Elastic Limit	Not over 55,000 lb. per sq. in.
Tensile Strength	Not over 117,000 lb. per sq. in.
Elongation in 2 in.	Not less than 15 per cent.
Reduction in Area	Not less than 25 per cent.

(d) **High Carbon Steel Hardened:**

Elastic Limit	Not less than 135,000 lb. per sq. in.
Tensile Strength	Not less than 180,000 lb. per sq. in.
Elongation in 2 in.	Not less than 3 per cent.
Reduction in Area	Not less than 12 per cent.
Shore Hardness	Not less than 85.

2. **Design.**—All pivots shall be designed and manufactured so that the two sides joining to form the knife edge shall make an angle that will not exceed 90 degrees; that the tolerance for offset of the knife edge of the pivot, as figured from the center line of the pivot at its base, shall be within 10 per cent of the width of the pivot for "machined in" pivots, and 15 per cent of the width of the pivot for "cast in" pivots.

3. **Mounting:**

(a) **Fastening.**—All pivots shall be firmly fastened in position, without swedging or caulking.

(b) **Machining.**—For Heavy Service Scales all pivots of the main levers shall be machined and fitted into machined ways.

(c) **Continuous Contact.**—All pivots shall be mounted so as to secure equal and continuous contact of the knife edges with their respective bearings for the full length of the parts designed to be in contact; in loop bearings the knife edges shall project slightly beyond the bearings in the loops.

(d) **Position.**—The pivots shall be so mounted that each knife edge in a given lever will be maintained in a horizontal plane under any load; and shall be so mounted that a plane bisecting the angle of a knife edge will be perpendicular to the horizontal plane established by the knife edges of the end pivots, and shall be so mounted that the knife edges in a given lever will be parallel to each other.

4. **Support for Projecting Pivots.**—The reinforcing on the levers to support projecting pivots shall be tapered off to prevent lodgment of dirt next to the pivots and to provide proper clearances.

5. **Fulcrum Distance.**—The distance between the fulcrum pivot knife edge and the load pivot knife edge in main levers of Heavy Service Scales shall be not less than 8 inches. For Light Service Scales it is recommended that this fulcrum distance shall be not less than 6½ inches.

6. **Location of Main Lever Load Knife Edges.**—The load knife edges of the main levers shall be so located that the center line of the live rails can be placed in the vertical plane established by the centers of those knife edges.

SECTION VIII—NOSE IRONS

1. **Design and Fastening.**—The nose irons shall be firmly fastened in proper position by means of screws or bolts of a recognized standard size and thread, or other equally effective mechanical device.

(a) **Design of Fastening.**—The means for clamping the nose irons in position shall be of such design that indentations in the lever will not be made, and shall be independent of any means provided for adjustment.

(b) **Direction of Fastening.**—The means for clamping nose irons in position shall force or hold them against the lever in the same direction as they would be forced by the load.

(c) **Control of Nose Iron Movement.**—The movement of the nose irons shall be controlled by means of adjusting screws of recognized standard size and thread. These screws shall be made of a material which will not corrode.

2. **Marking of Position.**—The position of each nose iron as determined by the factory adjustment, shall be accurately, clearly and permanently indicated by a well-defined mark on the lever and nose iron, which shall meet on a common line.

3. **Finish and Pivot Mounting.**—Those surfaces of the nose irons intended to come into slidable contact with the levers shall be made true so as to secure an accurate fit of the nose irons on or in the levers. Each nose iron shall be of such design that when adjustments are made the knife edge will be held parallel to its original position.

Section IX—Lever Fulcrum Stands

1. **Design:**

(a) **Height of Pillars and Area of Bases.**—The height of the pillars and the dimensions of the bases of the stands shall be sufficient to prevent a tipping action. In stands of the two pillar type, both pillars shall be of equal height.

(b) **Pillars, Position on Bases.**—The pillars or upright portions of the stands carrying the bearings shall be so placed on the bases that the centers of the bearing lines shall be over the centers of gravity of the bearing surfaces of the stands.

(c) **Anchor Bolt Holes.**—Two or more anchor bolt holes, not less than two inches in diameter, shall be provided in proper places in the bases of all the stands, unless other equally effective means for anchorage is provided.

2. **Qualities of Castings.**—The castings shall be free from blisters and large holes, or other imperfections, and shall be brought to a reasonably smooth finish.

3. **Bases for Lever Stands.**—The bases of the stands shall be finished to within a tolerance of $\frac{1}{32}$ inch, or machined when to be mounted on metal bed plates; accurate to a plane perpendicular to the axis of the upright portion of the stand, and the knife-edge bearing line shall be parallel to the surface of the base.

4. **Pillars, Finish of Tops.**—The tops of the pillars for receiving the bearing steels, caps or blocks shall be finished to a tolerance of $\frac{1}{32}$ inch.

5. **Tie Bars.**—Tie bars for the lever frames are not required, but if used, the contiguous surfaces shall be machined.

Section X—Bearings, Bearing Blocks and Links

1. **Material for Bearing Steels.**—The character of the material for bearing steels will be found under "Knife Edges," Section VII. The bearing steels shall be equal to or greater in hardness than the knife edges which oppose them. It is found good practice to have the bearing steels not less than 95 points hardness on the Shore recording scleroscope for high carbon steel, and not less than 90 for special alloy steel.

2. **Design of Bearings.**—Scales shall be so designed that when the load is applied to the live rails, the oscillation of the weigh-bridge will not displace the bearings at points of contact on the knife edges.

3. **Mounting of Bearing Steels.**—All like bearing steels shall be interchangeable or mounted in interchangeable bearing steel blocks. When the steels are separable and interchangeable in the blocks they shall be

fastened in position by means of set screws of a recognized standard size and thread, and of a material which will not corrode, or by other equally effective device.

4. **Finish of Bearing Steels and Bearing Blocks.**—The bearing surfaces shall be brought to a smooth, true and accurate finish to provide continuity of contact with the opposing knife edges.

5. **Weigh-Bridge Bearings.**—The tops of weigh-bridge bearings making contact with the weigh-bridge girders shall be finished to within $\frac{1}{32}$ inch of a true plane that will bring them all to the same height when in position, and in a plane parallel to the bottom of the bases of the fulcrum stands. These tops shall be provided with bolt holes of a sufficiently large diameter to allow for adjustment both transversely and longitudinally to secure a proper alinement of parts.

SECTION XI—LOOPS AND CONNECTIONS

1. **Design Proportion.**—In loops which form bearings for projecting pivots, the radius of the portion of the bearing making immediate contact with the knife edges and the radius of the eye of the loop shall be not less than the length of the longest side of the cross-section of the pivot to be used in the loop.

2. **Length.**—All loops in like connections, except where made adjustable, shall be of the same length.

3. **Steelyard Rod.**—The steelyard rod shall be equipped with a turnbuckle.

4. **Lock-Nuts.**—Bolts or turnbuckles used as a part of the connections shall be provided with lock-nuts.

SECTION XII—CHECKS

1. **Type.**—All weigh-bridges shall be checked by adjustable checks of the rod or other approved type which shall be equal to the rod type in functioning.

2. **Character.**—Both longitudinal and transverse checks shall be provided.

3. **Position.**—The checks shall be attached as high as possible and shall be horizontal, and parallel with or perpendicular to the vertical plane through the center line of the track according to whether they are longitudinal or transverse checks.

4. **Number.**—Not less than four longitudinal and eight transverse checks shall be provided. When the rod type is used, they shall be assumed to act in tension only.

5. **Strength.**—The combined area in square inches of the check rods at either end or side shall be not less than the sectional capacity in pounds divided by 60,000 when steel check rods are used.

SECTION XIII—WEIGH-BEAM AND ACCESSORIES

1. **Design:**

(a) **Capacity.**—The maximum capacity of the beam shall be not greater than 1⅔ times the sectional capacity.

(b) **Full Capacity Beam.**—Except for special cases a beam of the full capacity type shall be provided.

(c) **Shoulder Stop.**—A shoulder stop shall be provided on all beams to prevent the travel of the main poise back of the zero notch.

(d) **Notches.**—The number of notches for the main poise shall not exceed 6 per inch. Each notch shall be so made that when the pawl rests in it, a line projected from the center of the side of the notch nearer the zero graduation to the axis about which the pawl revolves will be perpendicular to that side of the notch.

(e) **Pawl or Latch.**—The tip or point of the pawl or latch shall be of the same width as the notches of the beam, and shall be rounded off so that a small amount of dust or dirt in the bottom of the notch will not prevent the poise from assuming its correct position.

(f) **Projections and Recesses.**—Poises shall be designed so as to present the least number of recesses or projections in or on which dust or dirt may accumulate.

(g) **Ball or Cone Bearings.**—Ball bearings, cone bearings or other means shall be provided to secure as free a movement of the poise along the beam as possible, but without sideplay of the poise.

(h) **Registering Beam.**—Scales that are to be used exclusively for spot weighing of cars or carload freight shall be equipped with a type registering, or other registering beam, of a capacity that will enable the entire load to be weighed in one draft, and without the use of additional weights of any kind, except for special weighing.

(i) **Fractional Bar Stops.**—On registering beams the fractional poise shall be equipped with means to insure a positive stop at any 20-pound interval, and a stop shall be provided to prevent the movement of the fractional bar beyond its proper travel in either direction.

(j) **Operating Lever.**—A substantial double or other approved type of hand grip shall be provided to facilitate the printing or registering of the weight on the ticket with the least possible disturbance of the beam.

(k) **Receptacle for Weight Ticket.**—On registering beams means shall be provided to prevent the placing of the weight ticket in its receptacle in any position in which an incorrect weight can be registered.

2. **Marking:**

(a) **Intervals.**—The notches and graduations on the main beam shall be made at the 1000-lb. intervals.

(b) **Length of Graduations.**—For the main beam the zero graduation and all graduations representing multiples of 10,000 lb. shall be ¾ inch in length. All graduations having values in thousands of pounds ending in 4 and 8 shall be ½ inch in length. All other graduations shall be ¼ inch in length, or the alternative method of marking may be used in which the marks representing 5, 15, 25, etc., thousand pounds shall be not less than 1½ times the intermediate lines, and every tenth line shall be longer than every fifth line, and the lengths of the graduations other than the 5s and 10s shall be not greater than twice the distance between their centers, preferably 1½ times the distance between their centers.

(c) **Size of Figures.**—For the main beam the zero graduation and every tenth graduation therefrom shall have its value in thousands of pounds (i. e., 0, 10, 20, etc.) marked by figures ⅜ inch in height, except the last graduation on beam, which shall be marked in full, for example, 200,000 lb. All other graduations, in beams graduated by the first method, having values in thousands of pounds ending in an even figure, namely, 2, 4, 6 and 8, shall be marked by figures 3/16 inch in height. On beams graduated by the second method the 5s, 15s, etc., may or may not have the value in thousands of pounds marked, or may have a star or other device placed opposite the line. No other graduations having readings in thousands of pounds ending in an uneven figure shall be marked. All numbers shall be placed directly beneath their respective graduations and shall be within 1/16 inch to ⅛ inch of the graduation.

(d) **Fractional Beam.**—For registering beams the graduations for the fractional beam shall be placed at 20-lb. intervals up to and including 980 lb., or if the fractional beam corresponds to a full 1000 lb., the last figure shall be marked to read 999 lb. Non-registering fractional beams shall be graduated in 50-lb. intervals, except for special cases.

3. **Balance Ball.**—A balance ball shall be provided and its movement shall be controlled by means of a self-contained hand operated screw or other device which will not require that the ball be rotated in making any adjustments. A means for locking the ball in position shall be provided. The balance ball shall be provided with vertical adjustment.

4. **Counterbalance Weights.**—If counterbalance weights are to be used, the lower end of the hanger stem shall be threaded; a cup for the loose balancing material shall be screwed to the lower end of the stem and each additional weight shall be provided with an elongated hole in the center through which the hanger stem may pass. No slotted counterbalance weights are to be used. When no counterbalance weights are necessary on top of the counterbalance cup the cavity shall be closed by a cover, secured in a positive manner. No counterbalance weights shall be used in any place in the scale, except at the beam.

5. **Multiplication.**—A pivot with a loop shall be provided at the tip of the beam. The multiplication to this pivot knife edge shall be 7000 or 10,000, which shall be plainly and permanently stamped on the beam.

6. **Identification of Parts.**—Each beam shall be given a serial number which shall be stamped on the beam. The pivots, poises and fractional bar shall have stamped on them identification marks to show to which beam each belongs, and the pivots shall be so marked as to indicate their proper positions in the beam.

7. **Type Figures.**—Type figures shall be made of a material sufficiently hard so that they will not easily become battered or defaced. The figures shall be plain and raised sufficiently high to insure a clear impression when the weight ticket or tape is stamped. They shall be so attached and secured in their proper places that they will not become loosened.

8. **Beam Fulcrum Stand:**

(a) **Design.**—The beam shall be supported on a stand provided with compensating bearings, and shall not be suspended. The height of the pillars and the dimensions of the base of the stand shall be such as to prevent a tipping action.

(b) **Height.**—The height of the stand, measured from the bottom surface of the base to the pivot bearing surface, shall not exceed 13 inches.

(c) **Finish.**—The bearing surface of the base of the stand shall be finished to a plane perpendicular to the axis of the upright portion of the stand, and the knife-edge line of the bearing shall be parallel to the base. The center of the bearing line shall be vertically over the center of gravity of the bearing surface of the base.

9. **Trig Loop:**

(a) **Material.**—The contact parts of the trig loop shall be made of a non-magnetic material.

(b) **Play of the Beam.**—The play of the beam in the trig loop shall be not more than 2 per cent of the distance from the trig loop to the knife-edge of the fulcrum pivot.

(c) **Pointer.**—The beam shall be fitted with a pointer to be used in connection with a fixed graduation or other device on the trig loop to indicate a central position in the trig loop when the beam is horizontal.

10. **Beam Support.**—Cast iron pillars or equivalent and a beam shelf shall be provided for all scales. The beam fulcrum and the trig stand shall be securely erected thereon. This shelf shall be strong and sufficiently rigid, so that it will not deflect to an extent that the action of the scale will be affected.

Section XIV—Anti-Friction Points and Plates

1. **Required.**—Anti-friction points and plates shall be provided to limit the relative lengthwise displacement of all knife edges with respect to their bearings.

2. **Material.**—The anti-friction points and plates shall be made of hardened carbon steel and the plates shall be at least as hard as the points which come in contact with them.

3. **Design.**—The anti-friction points shall consist of a point or projection of small area formed on the knife edge, in the case of full length contact knife edges, or shall be formed on plates securely attached to the levers or pivots. The design of the anti-friction points shall be such that they will always make contact with their opposing plates on the line of the knife edges, within practical limits. In loop bearings the parts which come in contact with the anti-friction points shall be formed without any points or projections so that, when the loop is relatively displaced in a direction at right angles to the knife edges, the contact will continue to be made with the anti-friction points on the line of the knife edge.

4. **Clearances.**—The clearances between the anti-friction plates and anti-friction points shall not exceed 1/16 of an inch on the beam, ⅛ inch on the shelf lever, and ¼ of an inch on all other levers, and the minimum clearances shall be not less than one-half these amounts respectively.

Section XV—Clearances

1. The clearance around and between the fixed and live parts of the lever system of a scale shall be at least ¾ of an inch except at points where other clearances are specified.

SECTION XVI—FACTORY ADJUSTMENTS

1. **Levers.**—The design, workmanship, and factory adjustment of the levers and beam shall be such that the proper ratio of the lever arms will be maintained.

2. **Beams.**—Each notch in the beam shall be adjusted to within .002 inch of the nominal distance from the zero notch.

SECTION XVII—INTERCHANGEABILITY

1. Like parts of all like scales of the same design and manufacture shall be interchangeable unless otherwise herein specified. The scale drawings and the parts of the scale shall be marked to indicate the proper positions of the parts in the scale, so as to prevent parts not symmetrically designed being incorrectly placed when the scale is set up.

SECTION XVIII—SENSIBILITY RECIPROCAL

1. **Definition.**—The sensibility reciprocal shall be that weight required to be added to or removed from the live rails to turn the beam from a horizontal position of equilibrium in the center of the trig loop to a position of equilibrium at either limit of its travel.

2. **Value.**—The sensibility reciprocal shall not exceed 50 lb. in any case.

SECTION XIX—TOLERANCE

1. The Manufacturers' tolerance to be allowed on the first field test, after installation corrections, of all new railway track scales shall not exceed 1/20 of 1 per cent, or 50 lb. per 100,000 lb., for any position of the test car load on the scale. The minimum test car load to be applied shall be 30,000 lb.

SECTION XX—LOCATION AND ELEVATION

1. **Foundation.**—Scales shall be so located that an adequate foundation, and at least 50 feet of tangent track at each approach to the live rails, can be provided.

2. **Elevation.**—The scale shall be raised with respect to the other tracks of the yard to such an elevation that the drainage of the surface water will be away from it. Means shall be provided to prevent surface water between the rails of the scale tracks from running into the pit.

3. **Right-Handed Beam.**—Scales shall be so located that a right-handed beam can be used in all cases without the use of extension levers, exclusive of shelf lever, between transverse extension lever and beam.

SECTION XXI—FOUNDATIONS

1. **Material.**—All scale foundations shall be constructed of concrete. The qualities of the materials and the methods of mixing and placing the concrete shall be in accordance with the railroad's specifications for first-class concrete, or other first-class engineering practice may be followed.

2. **Bearing Area.**—The bearing areas of the foundation footings shall be such that the bearing pressure on the soil will be uniform throughout and not exceed:

For fine sand or clay	4,000 lb. per sq. ft.
For coarse sand and gravel or hard clay	6,000 lb. per sq. ft.
For boulders or solid rock	20,000 lb. per sq. ft.

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity should be increased, by drainage, by adding a layer of gravel or broken stone, or by driving piles.

3. **Dimensions of Pit.**—The depth of the scale pit shall be not less than seven feet from the base of the rail to the finished floor of the pit. The width of the pit between faces of side walls shall be not less than ten feet for Light Service Scales, or less than ten feet six inches for Heavy Service Scales, provided that there shall be a horizontal clearance of not less than 16 inches between the faces of the side walls and the scale parts below the weigh-bridge girders and above the base of the stands. The length of the pit inside of end walls shall be not less than two feet greater than the length of the scale parts.

4. **Walls of Pit.**—The side and end walls shall be not less than 15 inches and preferably 18 inches thick at the top. The foundation walls of the scale house shall be not less than 12 inches thick at the top and shall be formed solidly to the side walls of the scale pit.

5. **Waterproofing.**—Where necessary to prevent seepage of water through foundations into the scale pit, they shall be waterproofed and drained into a waterproofed cistern located outside the scale pit and equipped with either pump, siphon or automatic "cellar drainer."

6. **Approach Walls.**—Approach walls or piers of concrete shall be built to extend at least 15 feet, preferably 25 feet, from the pit face of the end wall at the approach and back under the track, to preserve line and surface of approach tracks. They may be built in one solid mass of concrete or they may consist of two parallel walls or piers, but with either type of construction they shall have a single foundation footing. Where necessary to secure safe bearing capacity they shall be carried to the same depth as the pit walls.

7. **Wall Batter.**—All wall surfaces next to earth subject to freezing shall be constructed with a uniform batter of not less than one inch to the foot, and as much more as necessary to permit the heaving of adjacent ground by frost action without disturbing the walls.

8. **Footings or Piers for Lever Stands.**—The concrete footings or piers supporting the lever stands shall be not less than 18 inches thick. Their tops shall be above the floor of the pit a distance sufficient to prevent the accumulation of water under the bases of the stands, and they shall be finished to exact level and elevation to receive the lever stands directly without the use of shims or grouting. The floor of the pit may be a solid mat of concrete nearly the same thickness as that required to support the lever stands, or it may be not less than six inches thick where local conditions permit. The pit floor shall in all cases be smooth and with a pitch to a common point of drainage and free from pockets in which water will stand. If the scale is of a type having main levers or parts of the platform bearings that hang below the bases of the main lever stands, the piers shall be provided with recesses of a size to give a clearance of not less than 1½ inches and the recesses shall be formed to prevent lodgment of dirt.

9. **Anchor Bolts.**—Anchor bolts shall be provided in foundations for lever stands to match the bolt holes provided for securing the stands, and they shall extend into the concrete not less than 15 inches.

10. **Anchorage for Floating Levers.**—Floating levers, viz., a lever exerting an upward pull at its fulcrum, shall be anchored to the foundation to resist not less than twice the uplift produced by a train of capacity cars passing over the live rails.

11. **Deck Beam Supports.**—Inverted T-rails, or bearings of steel, shall be set in the side walls of the pit with the center of bearings of the beams not less than 6 inches from the inside face of the walls, but such bearings shall not be fastened to transverse beams.

12. **Beam Foundations.**—The pillars supporting the beam shelf shall rest upon a reinforced concrete floor, steel beams or reinforced concrete beams, but the pillars and supporting beams, if used, shall be independent of the scale house floor if of timber construction. When it is necessary to install the scale beam in any building other than a regulation scale house, the pillar support shall rest on foundations independent of the building unless the foundation of the building is free from vibrations and settlement.

Section XXII—Scale Beam House

1. **Design.**—The minimum inside width of the scale house shall be 4 feet, and the minimum length shall be sufficient to allow the installation therein of a full-sized beam shelf and regulation beam of proper capacity for the scale, and self-recording attachment if used. It shall be provided with a bay window, or front and end windows, located with their sills about on a level with the top of the beam shelf, and of sufficient size to give the weigher a clear and unobstructed view of the scale deck and approaching cars so that he can read the car numbers and stenciled light weights when he is weighing. The windows shall be glazed with clear glass, or clear wire glass, free from bubbles or other imperfections.

2. **Clearances.**—The lateral clearance between the scale house and the center of any track shall be not less than 7 feet 6 inches, or greater, if required by law or by the railway. A clearance of not less than one inch shall be provided between the inside of the scale house and beam supports and shelf.

3. **Ventilation.**—Where a scale beam house is not provided with artificial heat a ventilator in the roof shall be provided.

Section XXIII—Setting of the Scale

1. **Fastening of Stands.**—After alining the stands, large washers shall be applied to the anchor bolts and the nuts brought down tight. The anchor bolt holes in the castings shall be filled with cement, sulphur or other suitable material.

2. **Alinement.**—All levers shall be level and connections plumb throughout the scale.

Section XXIV—Scale Weigh-Bridges

1. **Type of Girders.**—In scales of more than two sections, weighbridge girders may be either of the continuous type or the non-continuous type, but non-continuous girders of such design of joints over centers of bearings as will admit of flexure vertically without derangement of sections are recommended.

2. **Steel Specifications.**—Structural steel work shall conform to the Specifications for Steel Railway Bridges of the American Railway Engineering Association.

3. **Size and Strength.**—The following table of Scale Capacities and Weigh-bridge Girders gives the required sizes for weigh-bridge girders. This table is based on a representative car having two axle trucks 22 feet from center to center, truck axles 5 feet 6 inches center to center and 12 feet center to center of adjacent end trucks of coupled cars.

4. **Bracing.**—Each weigh-bridge span shall be designed for a lateral force of 200 lb. per linear foot plus 4 per cent of the sectional capacity of the scale, applied at the top of the live rail and uniformly distributed.

(a) **Diagonal Bracing.**—Diagonal bracing shall consist of not less than 3 inches by 3 inches by ⅜ inch angles and not less than three diagonals per span shall be used, or the equivalent of this bracing shall be employed.

(b) **Transverse Bracing.**—To carry the lateral load to the knife edges of the main levers, each span shall be provided at its ends with a transverse bracing, of which the section modulus shall be not less than that determined by the formula:

$$S=\frac{1}{4}\ \frac{(0.04C+200L)d}{10000}$$

Where:

$S =$ section modulus,
$C =$ sectional capacity in pounds,
$L =$ length of span in feet,
$d =$ distance in inches from knife edge of main lever to top of live rail, or to top flange of girder if ties are used or when pedestals are braced to resist tipping transversely to the girder.

Intermediate transverse bracing shall also be provided of a section not less than that used in the ends of the span.

(c) **Stiffeners.**—Not less than one pair of stiffener angles, other than splicing angles, shall be provided over each bearing of the girders in each span of the weigh-bridge. The ends of these stiffeners shall be milled to fit the fillets of the girder flanges.

5. **Live Rail Pedestals.**—The live rail shall be carried on metal pedestals, which shall be mounted on metal ties or directly on the weigh-bridge. It is recommended that, when practicable, the pedestals mounted directly on the girders be cast or fabricated in units of two, set lengthwise with the girder to prevent the tilting action of the stands, produced by the deflection of the rails under load, and that they be transversely braced. Where pedestals mounted directly on weigh-bridge girders are used they shall be so designed that they will transfer the specified lateral load to the weigh-bridge. Where cast pedestals make contact with the rail they shall have their tops machined to grade or parallel to the bottoms of the pedestals. The bottoms of the pedestals shall be machined or type metal shall be used to pour between the base and the surface on which it rests.

6. **Fabrication and Assembly.**—In order to avoid distortion, each pair of weigh-bridge girders shall be fabricated complete with sway and lateral bracing in the shop under proper inspection where practicable; where

Scale Capacities and Weigh-Bridge Girders.

Length of Scale C. to C. End Sections,	Span C. to C. of Sections,	Main Lever Capacity,	Dead Load Main Lever Reaction,	Live Load Main Lever Reaction,	Bureau of Standards Representative Car			Dead Load Moment One Girder	Required Section Modulus	Alternative Girder Sections					
					Wheel Load,	Car Load,	Live Load Moment One Girder			Bethlehem Girder Beam		Double I-Beams		Single I-Beams	
										Sizes	Sec. Mod.	Sizes	Sec. Mod.	Sizes	Sec. Mod.
feet	feet	pounds	pounds	pounds	pounds	tons	inch lbs. ÷ 1000	inch lbs. ÷ 1000	(f=10000)						
						60 TON SECTIONAL CAPACITY									
45	15	60,000	3,750	56,250	23,440	93.76	1,476.7	84.4	156.1	18"x92#	176.8	....	......	1-24"x80#	173.9
48	16	60,000	4,000	56,000	22,400	89.60	1,612.8	96.0	170.9	18"x92#	176.8	....	......	1-24"x80#	173.9
50	16.67	60,000	4,170	55,830	21,810	87.24	1,704.5	104.3	180.9	18"x92#	176.8	....	......	1-24"x90#	186.5
51	17	60,000	4,250	55,750	21,540	86.16	1,744.7	108.4	185.3	18"x92#	176.8	....	......	1-24"x90#	186.5
54	18	60,000	4,500	55,500	20,810	83.24	1,872.9	121.5	199.4	20"x112#	234.2	....	......	1-24"x100#	198.3
56	18.67	60,000	4,670	55,330	20,390	81.56	1,960.4	130.8	209.1	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
57	19	60,000	4,750	55,250	20,190	80.76	1,998.8	135.4	213.4	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
60	20	60,000	5,000	55,000	19,640	78.56	2,121.1	150.0	227.1	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
63	21	60,000	5,250	54,750	19,160	76.64	2,241.7	165.4	240.7	20"x112#	234.2	2-20"x65#	234.0	1-24"x105#	234.3
66	22	60,000	5,500	54,500	18,730	74.92	2,360.0	181.5	254.2	24"x120#	300.6	2-24"x80#	347.8	....	......
69	23	60,000	5,750	54,250	18,350	73.40	2,523.1	198.4	272.2	24"x120#	300.6	2-24"x80#	347.8	....	......
72	24	60,000	6,000	54,000	18,000	72.00	2,687.4	216.0	290.3	24"x120#	300.6	2-24"x80#	347.8	....	......

75 TON SECTIONAL CAPACITY

45	15	75,000	3,750	71,250	29,690	118.76	1,870.5	84.4	195.5	20″x112#	234.2	2-20″x65#	234.0	1-24″x105#	234.3
48	16	75,000	4,000	71,000	28,400	113.60	2,044.8	96.0	214.1	20″x112#	234.2	2-20″x65#	234.0	1-24″x105#	234.3
50	16.67	75,000	4,170	70,830	27,670	110.68	2,162.4	104.3	226.7	20″x112#	234.2	2-20″x65#	234.0	1-24″x105#	234.3
51	17	75,000	4,250	70,750	27,340	109.36	2,214.5	108.4	232.3	20″x112#	234.2	2-20″x65#	234.0	1-24″x105#	234.3
54	18	75,000	4,500	70,500	26,440	105.76	2,379.6	121.5	250.1	24″x120#	300.6	2-24″x80#	347.8	....	......
56	18.67	75,000	4,670	70,330	25,910	103.64	2,491.1	130.8	262.2	24″x120#	300.6	2-24″x80#	347.8	....	......
57	19	75,000	4,750	70,250	25,670	102.68	2,541.3	135.4	267.7	24″x120#	300.6	2-24″x80#	347.8	....	......
60	20	75,000	5,000	70,000	25,000	100.00	2,700.0	150.0	285.0	24″x120#	300.6	2-24″x80#	347.8	....	......
63	21	75,000	5,250	69,750	24,410	97.64	2,856.0	165.4	302.1	24″x120#	300.6	2-24″x80#	347.8	....	......
66	22	75,000	5,500	69,500	23,890	95.56	3,010.1	181.5	319.2	24″x140#	350.1	2-24″x80#	347.8	....	......
69	23	75,000	5,750	69,250	23,420	93.68	3,220.3	198.4	341.9	24″x140#	350.1	2-24″x80#	347.8	....	......
72	24	75,000	6,000	69,000	23,000	92.00	3,433.9	216.0	365.0	24″x140#	350.1	2-24″x80#	347.8	....	......

100 TON SECTIONAL CAPACITY

45	15	100,000	3,750	96,250	40,100	160.40	2,526.3	84.4	261.1	24″x120#	300.6	2-24″x80#	347.8	....	......
48	16	100,000	4,000	96,000	38,400	153.60	2,764.8	96.0	286.1	24″x120#	300.6	2-24″x80#	347.8	....	......
50	16.67	100,000	4,170	95,830	37,440	149.76	2,925.9	104.3	303.0	24″x120#	300.6	2-24″x80#	347.8	....	......
51	17	100,000	4,250	95,750	36,990	147.96	2,996.2	108.4	310.5	24″x120#	300.6	2-24″x80#	347.8	....	......
54	18	100,000	4,500	95,500	35,810	143.24	3,222.9	121.5	334.4	24″x140#	350.1	2-24″x80#	347.8	....	......
56	18.67	100,000	4,670	95,330	35,120	140.48	3,376.6	130.8	350.7	24″x140#	350.1	2-24″x80#	347.8	....	......
57	19	100,000	4,750	95,250	34,800	139.20	3,445.2	135.4	358.1	26″x150#	396.5	2-24″x100#	396.6	....	......
60	20	100,000	5,000	95,000	33,930	135.72	3,664.4	150.0	381.4	26″x150#	396.5	2-24″x100#	396.6	....	......
63	21	100,000	5,250	94,750	33,160	132.64	3,879.7	165.4	404.5	26″x150#	396.5	2-24″x100#	396.6	....	......
66	22	100,000	5,500	94,500	32,480	129.92	4,092.5	181.5	427.4	28″x165#	468.8	2-24″x105#	468.6	....	......
69	23	100,000	5,750	94,250	31,880	127.52	4,383.5	198.4	458.2	28″x165#	468.8	2-24″x105#	468.6	....	......
72	24	100,000	6,000	94,000	31,330	125.32	4,677.6	216.0	489.4	28″x165#	468.8	2-24″x105#	468.6	....	......

Beams in pairs to be spaced 12 inches, center to center.

this method is impracticable and where field assembly is necessary, each pair of girders shall be placed in proper alinement and the bracing then introduced and secured by bolts or rivets.

7. **Live Rails:**

(a) **Weight.**—The weight and section of the live rails shall be the same as that of the dead rails. (See Section XXVII.)

(b) **Length.**—Full length live and dead rails without splices are desirable where they can be secured, but in all cases new rails shall be used, and where splices are necessary they shall be accurately applied.

8. **Clearance Along Live Rails.**—The clearance between the live rails or their pedestals and rigid deck shall be not less than 1½ inches, and the openings shall be protected from the weather and dirt.

SECTION XXV—APPROACH RAILS

1. Positive means shall be provided to prevent creeping of the ends of approach rails, and to maintain a clearance which shall be not less than ¼ inch nor more than ¾ inch between the approach rails and the live rails unless some special means is employed to reduce impact when wheel loads pass from approach rails to live rails. The effects of rail creeping may be eliminated by the use of switch points and bent stock rails placed in the approach track in the same alinement and plane with the live rails; each switch point to be set with its squared end either next adjacent to the live rail on the scale, or with an intermediate rail between the switch point and the live rail, and securely anchored to the approach piers by means of bolts anchored therein.

SECTION XXVI—DECK

1. **Type.**—The deck or platform shall be of the fixed type, except to meet special cases.

2. **Construction.**—The material for the deck shall be either reinforced concrete, wooden planking, or metal plates covered to prevent slipping, and as impervious to water as practicable.

3. **Clearances.**—The clearance between the bottom of the fixed deck beams or deck supports and the I-beams forming the weighbridge shall be not less than 2 inches.

SECTION XXVII—DEAD RAILS AND DEAD RAIL BEAMS

1. **Dead Rails When Required.**—Scales shall be installed with dead rails or relieving apparatus, except to meet special requirements.

2. **Weight of Rails.**—The weight of rails when supported on floor beams spaced 2 feet 6 inches center to center shall be not less than that given in table corresponding to the axle load; for greater spacing of the floor beams the weight of the rails shall be correspondingly increased.

Axle Load, Pounds	*Weight of Rail, Pounds*
50,000	80
55,000	85
60,000	85
65,000	90
70,000	100

3. **Transverse Beams Supporting Dead Rail:**

(a) **Structural Steel Work.**—Structural steel work shall conform to the Specifications for Steel Railway Bridges of the American Railway Engineering Association.

(b) **Strength.**—The following tables give the sizes and strengths required for the transverse floor beams for different axle loads and the stated assumptions:

ASSUMPTIONS: 11′-0″ c. to c. of bearings.
Dead rail offset 16 in.
Floor beams 2′-6″ c. to c.
75 per cent of axle load carried by one beam.
Dead rails 4′-11″ c. to c.

Axle Loads	Live Load Moments in 1,000 In. Lb.	Required Section Moduli (f-10,000)	Alternative Floor-beam Sections			
			Bethlehem Beams		I-Beams	
			Sizes	Sec. Mod.	Sizes	Sec. Mod.
50,000	745.7	74.6	1-15"x54#	81.3	1-15"x60#	81.2
55,000	820 3	82.0	1-15"x54#	81.3	1-15"x60#	81.2
60,000	894.9	89.5	1-15"x73# Girder	117.8	1-15"x75#	92.2
65,000	969.5	96.9	1-15"x73# Girder	117.8	1-15"x80# or 2-15"x42#	106.1 117.8
70,000	1044.0	104.4	1-15"x73# Girder	117.8	1-15"x80# or 2-15"x42#	106.1 117.8
75,000	1118.6	111.9	1-15"x73# Girder	117.8	1-15"x90# or 2-15"x42#	112.7 117.8

ASSUMPTIONS: 11′-6″ c. to c. of bearings.
Dead rail offset 16 in.
Floor beams 2′-6″ c. to c.
75 per cent of axle load carried by one beam.
Dead rails 4′-11″ c. to c.

Axle Loads	Live Load Moments in 1,000 In. Lb.	Required Section Moduli (f-10,000)	Alternative Floor-beam Section			
			Bethlehem Beams		I-Beams	
			Sizes	Sec. Mod.	Sizes	Sec. Mod.
50,000	799.3	79.9	1-15"x54#	81.3	1-15"x 60#	81.2
55,000	879.3	87.9	1-15"x64#	88.6	1-15"x 70#	88 5
60,000	959.2	95.9	1-15"x73# Girder	117.8	1-15"x 80# or 2-15"x 42#	95.8 117.8
65,000	1039.1	103.9	1-15"x73# Girder	117.8	1-15"x 80# or 2-15"x 42#	106.1 117.8
70,000	1119.0	111 9	1-15"x73# Girder	117.8	1-15"x 90# or 2-15"x 42#	112.7 117.8
75,000	1199.0	119.9	1-15"x104# Girder	162.7	1-15"x100# or 2-15"x 42#	120.1 117.8

SECTION XXVIII—WEATHER AND DIRT SHIELDS

1. **Weather Guards.**—Substantial metal guards shall be provided to cover the openings between the live rails and the deck to exclude dirt, snow and rain. They shall be so designed and fastened in place that they will be secure, but may be easily removed for inspection or repairs.

2. **Dirt Shields.**—Substantial metal shields shall be provided throughout the pit, over all scale bearings and connections, applied to the deck, structural steel, or scale parts to prevent water or dirt falling into them or the accumulation of dirt or ice at points where it would interfere with the action of scale parts.

SECTION XXIX—LIGHT, DRAINAGE, VENTILATION AND CLEANING

1. **Light.**—Proper lighting of the scale weighing beam, scale house, scale deck and scale pit shall be provided.

2. **Drainage.**—The scale pit should be kept free from water by adequate drainage.

3. **Ventilation:**

(a) **Requirements.**—All scale pits shall be ventilated to meet the needs of each particular case, the object being to have the least possible amount of moist air in the pit to prevent rusting of scale points and structural steel.

(b) **Automatic Natural Ventilation.**—The following arrangement is recommended for securing natural ventilation:

An opening should be made to the pit at each corner to connect with flues which terminate near the bottom of the pit, and another opening without flues extending downward should be made into the pit at its top and near its center. With such an arrangement circulation will always tend to be set up by the air whenever the pit is warmer or more moist than the outside, and when the pit is cooler or drier than the outside, circulation will tend automatically to stop. When this is done circulation will be set up only when it will tend to dry the pit.

SECTION XXX—ENTRANCE TO SCALE PIT

1. **Location.**—Entrance to scale pit for the purpose of inspection shall be through either the floor of the scale house or foundation wall, and shall be closed by a suitable door so fastened as to prevent entrance of unauthorized persons.

2. **Hatches in Deck.**—If it is desired to have hatches or openings in the deck, except such as are provided for ventilation, they shall be securely fastened from the inside of the pit.

SECTION XXXI—PROTECTION FROM CORROSION

1. **Shop Painting.**—When no shop inspection is provided the steel castings and structural steel shall be given one shop coat of boiled linseed oil only. Other parts shall be painted one shop coat of red lead only. When shop inspection is provided, all parts of the scale mechanism and structural steel shall be given one coat of red lead paint after inspection. In riveted work surfaces coming in contact shall be given one coat of red lead paint before being riveted together. All parts inaccessible after erection shall be given a second shop coat of red lead paint.

2. **Field Painting.**—Scales and structural steel work shall be cleaned and painted with one coat (and preferably two coats) of paint in the field before installation.

[11]RULES FOR THE LOCATION, MAINTENANCE, OPERATION AND TESTING OF RAILWAY TRACK SCALES

SECTION I—LOCATION

1. **General Conditions.**—The proper location of track scales depends principally on the following conditions:

(a) **The volume of traffic to be weighed in comparison with that switched over the scales and not to be weighed.**—The presence of the scale in a much used track is a source of increased cost of maintenance and difficulty in inspecting and testing as well as dangerous to trainmen. In general, in yards not operated by gravity, the scale should not be located in a main drilling lead unless the number of cars to be weighed exceeds 60 per cent of the total number of cars handled or unless the total number of movements over the main drilling lead is comparatively small.

(b) **Whether the scale is to be equipped with dead rail or relieving gear.**—Dead rails should be provided for four-section scales.

(c) **Whether a run around track will be installed for switching with a separate track for weighing.**—Where spot weighing is done the run around track is desirable. If cars are to be weighed as classified, the weighing track need be only long enough to clear the dead rail switches. If cars are to be weighed in solid cuts, the weighing track should be long enough to hold a cut of cars to be weighed, both before and after being weighed, in order not to block operation of other tracks while weighing is being done. The weighing track may be located alongside of the drilling track, alongside of the ladder track or on an outer yard track.

(d) **Whether cars are to be weighed spotted or in motion.**—If cars are to be weighed in motion the scale must be on a gradient in the drilling track at the head of the classification yard.

(e) **The cost of extra switching when the scale is not located on the lead to the classification tracks.**—Ordinarily the cost of the extra switching may be ignored when the integrity of the weights would be affected.

(f) **The cost of maintenance when the scale is located on the lead to the classification tracks and only a small proportion of the cars are to be weighed.**

(g) **The necessity for quick dispatch of cars that are weighed.**

(2) **Position of Live and Dead Rails.**—Live rails should be on the offset line and the dead rails straight unless a large portion of the cars are to be weighed. For motion weighing the offset should be divided, unless the resistance is equalized by means of a spring switch.

3. **Gradients for Motion Weighing:** NOTE.—Attention is called to the following provision of the "National Code of Rules Governing the Weighing and Re-Weighing of Carload Freight"—A.R.A. Circular 1433, May 29, 1914, approved by the I.C.C., June 9, 1914:

"Rule 3-c.—Cars may be weighed in motion only when uncoupled and free at both ends and alone upon scales properly designed for weighing in motion and in charge of a competent weighmaster."

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[11] Adopted, Vol. 21, 1920, pp. 886, 1446; Vol. 28, 1927, pp. 612, 1409; Vol. 29, pp. 399, 1334; Vol. 30, 1929, pp. 407, 1400.

(a) GRADIENTS ABOVE THE SCALE.—The distance and gradients from the apex of the hump to the higher end of the scale should be so related to the length of the scale and the gradient of the scale rails that a minimum weighing time per car of four seconds will be secured for free running cars.

(b) GRADIENTS ACROSS THE SCALE.—The gradient of the scale rails should not exceed one per cent, and the gradient of the track for at least ten feet in each direction from the scale should be the same as that of the scale rails.

(c) GRADIENTS BELOW THE SCALE.—The gradients of the track and the lengths of such gradients below the scale should be such that cars will run by gravity as far away from the scale as desired when their speed over the scale does not exceed that necessary to provide a weighing period of four seconds. Where local conditions make it advisable for car riders to take cuts of two or more cars into the classification yard, the gradient of the scale rails should extend for at least 100 and preferably 200 feet below the scale to enable weighed cars to be assembled in cuts without excessive impacts and to permit all cars involved to be free of the scale when impacts occur.

4. **Runoff Gradient for Spot Weighing.**—When a scale is installed not in connection with a hump, it is desirable that it be high enough to permit cars to run away from the scale by gravity after being weighed.

SECTION II—MAINTENANCE AND OPERATION

1. **Numbering Scales.**—All track scales should be numbered and referred to by number and location.

2. **Scale Shop.**—Extensive repairs to scales, such as the renewal or the sharpening of pivots, should be made in a properly appointed shop.

3. **Cleaning.**—When scales are in service regularly, scale parts, substructure and foundations should be cleaned at least twice a month, and when exposed to the elements, or otherwise so located that they are liable to become clogged with ice or dirt, should be cleaned oftener.

4. **Rust Preventive for Pivot and Bearing Steels.**—The best rust preventive obtainable should be applied to pivot and bearing steels, but it should be so applied as not to interfere with the proper working of the scale.

5. **Removal of Ice.**—If ice obstructs the action of the scale, salt should not be used to melt it; artificial heat should be used.

6. **Standing of Equipment Prohibited.**—Equipment should not be allowed to stand on the scale, except when being weighed.

7. **Restrictions to Use of Live Rails.**—Engines or similar heavy equipment should not be passed over the live rails, except on authority of the department having supervision over the installation and maintenance of scales. The unnecessary passing of cars over the live rails should be prohibited. Weighed cars which have passed beyond

the dead rail switch must not be returned over the live rails. The dead rail switches should be set for the dead rail track except when cars are being weighed.

8. **Cars Restricted to Live Rails or Dead Rails Only.**—Cars on the live rails must not be moved by cars or engines on the dead rails or vice versa. Cars must not be moved over the scale with one truck on the live rails and another truck on the dead rails.

9. **Use of Sand and Injector by Enginemen Prohibited.**—Enginemen must not apply sand or use the injector when on the scale. The slipping of engine drivers on either live or dead rails is injurious to the structure and should be avoided.

10. **Weigh-beam.**—The weigh-beam should be balanced before the scale is used. When not in use it should be secured by the beam catch and with the poise set at the highest graduation.

11. **Stopping Cars on Scales.**—Cars should not be stopped on the scale by impact, by the sudden application of brakes or by throwing obstructions under the wheels. When pushing off the scale cars which have been stopped for weighing or otherwise, impact must not occur at a speed greater than two miles per hour. When necessary for any reason to run cars over the live rails, the speed should not exceed four miles per hour.

12. **Automatic Weighing and Recording.**—Where automatic weighing and recording devices are used it is absolutely necessary that both the scale and the automatic devices be in first-class condition, with properly maintained approach track, and cars must be run at a slow rate of speed with particular attention to steadiness of motion which is essential to obtaining best results.

13. **Locking Scale Houses.**—Scale houses and beam boxes must be kept locked when not being used.

14. **Inspection by Weighmaster.**—The weighmaster should familiarize himself with the construction of the scale and make inspections at such intervals as are necessary to determine whether or not the scale is in proper working condition. The weighmaster and anyone appointed to inspect and clean the scale should be properly instructed, and it is desirable that they be present with the scale inspector when the scale is tested.

15. **Painting.**—The scale mechanism and structural steel should be painted often enough to prevent corrosion.

Section III—Testing

1. **Tests with Single Test Cars.**—Track scales in regular car weighing service should be tested at least every three months with a test car weighing not less than 30,000 lb.

2. **Graduated Tests.**—Scales when installed and periodically thereafter should be given a graduated test with two or more test loads up to the weight of the heaviest cars normally weighed. The frequency with which such graduated tests should be made depends on the design, capacity

and method of installation of the scale used, the wear of scale pivots, and the amount of weighing performed.

3. **Weekly Tests.**—A test should be made each week by weighing a heavily loaded freight car with as short a wheel base as is obtainable on each end and center of scale. When the scale is equipped with an automatic weighing attachment the car should, in addition to the above, be weighed spotted on the trip end of the scale and in motion with the automatic attachment connected. A report of these tests should be sent to the officer in charge of scales and weighing.

4. **Daily Tests.**—In addition to the above, a daily test should also be made on each scale equipped with an automatic attachment, by weighing a car spotted on the trip end of the scale with the beam, also in motion with the automatic attachment connected. A book record of this and other tests should be kept by the weighmaster.

5. **Adjustment.**—Track scales should be kept in the closest possible adjustment, and a scale should be considered inaccurate when it cannot be adjusted, and such adjustment maintained to within two lb. to 1,000 lb., in excess or deficiency, when distributed test is made with two or more test loads. When only concentrated sectional tests are made, the maximum error for any position of the test load should not exceed three lb. to each 1,000 lb. of test load used.

The sensibility reciprocal of a track scale should never be more than 100 lb.

SECTION IV—EQUIPMENT FOR TESTING

1. **Standard of Mass.**—The standards of mass for testing scales should be derived from primary weights, verified by the U.S. Bureau of Standards, to within what is known as their "Class B Tolerance." Such weights can be obtained either direct or through scale manufacturers. The 50 lb. secondary or working cast-iron weights, which are transported from place to place and used directly in testing scales, should be rectangular, and of such design as to facilitate stacking; they should be free from pockets, blow holes, etc., which are liable to catch and hold foreign matter. No adjusting cavity or cavities in the bottom of the weights should be permitted.

These weights should be properly painted, surfaces maintained in good condition, and be tested and adjusted in comparison with master-weights, which have been verified to within "Class C Tolerance." The working weights shall be adjusted to within 25 grains and maintained to within 100 grains of their true values.

NOTE.—The standards for testing scales in the Republic of Mexico must be in accordance with the metric system standards and will be verified by a Federal scale inspector in accordance with the Federal laws.

2. **Even Arm Balance and Master Scales.**—It is desirable for verifying or scaling test weights and test cars to have, in addition to standards of mass prescribed above;

(a) An accurate even arm balance of 100 lb. capacity in each pan, sensitive when loaded to two grains.

(b) A master scale.

SECTION V—GENERAL SPECIFICATIONS FOR MASTER SCALES

1. The master scale shall be of sufficient length and capacity for sealing test-weight cars and should be installed under cover, at a location as free from vibrations, resulting from machinery, train or other causes, as possible. The use of it should be limited to the verification of test cars or for other special weighing where extreme accuracy is required. It should not be used for general weighing purposes, nor be run over with cars or material not to be weighed. A scale of the two-section track scale type is recommended.

2. The length of weighing rail should be sufficient to weigh in one operation test cars in use or contemplated. Scale with weighing rail not less than 10 feet in length is recommended. The approach rails to master scale should be on a tangent for a distance slightly in excess of the longest wheel base cars to be weighed on the scale. To facilitate test with equipment such as is used by the Bureau of Standards, the tangent on at least one approach should be not less than 50 feet.

3. The capacity of scale should be determined by the heaviest load to be weighed upon it when concentrated on a 5 foot wheel base, without stresses being developed in the parts of the scale in excess of those specified in Section IV of the Specifications for Four-Section Railway Track Scales. A scale of not less than 100,000 lb. is recommended.

4. The scale should be equipped with a single beam with a capacity not to exceed 1,000 lb., the value of minimum graduations not to exceed 5 lb. Multiplication at butt of beam 100 to 1, multiplication of the beam 10 to 1, and ratio of counterweights 1,000 to 1 are recommended.

5. The angular movement of the beam should be limited by the trig-loop, and should be 2 per cent of the distance between the trig-loop and the fulcrum knife-edge.

6. The sensibility reciprocal should correspond to 50 per cent of the angular movement of the beam. The sensibility reciprocal should never be greater than 5 lb.

7. Master scale, when installed, and at least once each year thereafter, should be given a graduated test up to the weight of the heaviest loads to be weighed upon it (preferably to full capacity).

Tolerance on counter poise weights is as follows:

Weight Pounds	*Tolerance Grains*	*Weight Pounds*	*Tolerance Grains*
50	10	2.	1.5
25	6	1.	1.0
20	6	0.8	1.0
15	4	0.5	0.5
10	4	0.4	0.5
8	3	0.3	0.5
5	3	0.2	0.5
4	2	0.1	0.3
3	2		

Master scales should be capable of being adjusted and maintained to within the tolerances for adjustment and maintenance, respectively, as given in the following table:

Test Load	*Tolerance in Pounds*	
Pounds	*For Adjustment*	*For Maintenance*
20,000	3.00	6.00
30,000	3.68	7.36
40,000	4.24	8.48
50,000	4.75	9.49
60,000	5.20	10.40
70,000	5.62	11.22
80,000	6.00	12.00
90,000	6.37	12.74

8. To facilitate calibration of master scales, the use of special weights heavier than the usual 50-lb. commercial test weights are desirable.

Tolerance of Weights weighing respectively 2500, 5000 and 10,000 pounds is as follows:

Weight	*Tolerance*	
Pounds	*Grains*	*Pounds*
2,500	440	.063
5,000	650	.093
10,000	975	.139

9. Master scales should be kept clean, dry and free from rust, and it is recommended that this work be looked after only by an experienced scale man.

Note.—The following sections and paragraphs in the Specifications for the Manufacture and Installation of Four-Section Railway Track Scales, apply also to master scales.

Section III, and IV, Sec. V, paragraph 1; Section VI, paragraphs 1 to 5, inclusive; Secs. VII, VIII, IX, X, and XI, Sec. XII, paragraphs 1 to 3, inclusive; Sec. XIII, paragraphs 1c, 3, 4, 6, 8 (a), 8 (c), 9, and 10; Secs. XIV, XV, XVI, and XVII; Section XVIII, paragraph 1, Sec. XXI, paragraphs 1, 2, 4, 5, 7, 8, 9, 12; Secs. XXIII and XXVIII; Sec. XXIX, paragraphs 1 to 3 (a), inclusive, and Sec. XXXI.

It should not be overlooked that extraordinary care is necessary in the design and installation of master scales, and preparation of foundation to insure stability, in order that scales will meet the sensibility and tolerance requirements specified above, and consistently hold their adjustment as determined by repeated weighings.

Section VI—Test Weight Cars

1. For general track-scale testing test weight cars should weigh not less than a total of 30,000 lb., nor more than 80,000 lb. For making graduated tests and to simplify computations, cars weighing 80,000 lb. and 40,000 lb., respectively, are suggested. The maximum weight of 80,000 lb. is suggested principally in order to reduce the number of restricted movements due to weight limits on scales, bridges, etc.

2. Test weight cars should have following characteristics:

(a) All-metal construction.
(b) Length of wheel-base not to exceed 7 feet.
(c) Load distributed uniformly on wheels.
(d) No unnecessary ledges or projections likely to catch and hold dirt.
(e) No unnecessary parts.
(f) Strength and durability, so that frequent repairs will not be necessary.
(g) Surface area reduced as much as possible, to limit wind pressure.
(h) Accessibility of all parts for inspection.
(i) Roller or ball bearings of proper design, preferably the former.

3. Test weight cars should preferably be of the self-contained type with solid body in which a small space is provided for a limited number of test weights. When it is impracticable to provide a self-contained car, a compartment car, with body of structural and plate steel, at least one-half of the weight of which consists of test weights carried in the compartments, may be found to be serviceable.

(See paragraph 9 below.)

4. Test weight cars should be handled on the rear end of trains, just ahead of the caboose.

5. Test weight cars should not be kept in trains in yards during switching, but should be so placed that rough handling will be avoided. In no case should these cars be subjected to impact at a speed greater than two miles per hour.

6. All excess weight, resulting from accumulations of snow or ice, should be removed from test weight cars before they are placed on scales for the purpose of testing or on a master scale for calibration. The use of steam is recommended for this purpose.

(See paragraph 11 below.)

7. Test weight cars should be calibrated on a certified master scale before being started on each general test trip, and not less frequently than once every three months. At the time of calibration the actual weight of the car should be made equal to its nominal weight, which should be a multiple of 10,000 pounds.

8. Each test weight car should be in the care of but one scale inspector between calibrations, and he should be held personally responsible for the maintenance of the correct weight of each car in his care. To this end, the following rules should be enforced:

(a) No repairs to any test weight car may be made except in the presence of the scale inspector in charge thereof.

(b) Journals of test weight cars may not be repacked unless directed by the scale inspector in charge thereof.

(c) Each test weight car should carry a conspicuous badge plate, visible from either side of the car, and carrying a notice to the following effect:

"Do not oil or repack boxes or make repairs to this car unless directed by scale inspector."

(d) Should any change be made in the weight of a test weight car, it is the duty of the scale inspector to determine the amount of such change and immediately to make suitable correction. If the change in weight cannot be determined satisfactorily, the car should be returned to the master scale for calibration before again being used.

9. The nominal weight of each test weight car should include the car proper and everything contained therein, excepting only such material as is specifically carried as supercargo. This material, consisting of tools, overclothes, etc., when carried, should be contained in a removable steel box, the outside of which should be stencilled to show that it is not a part of the test load. This box and its contents must be removed from the car when being calibrated and when used for testing track scales.

10. When a test weight car is returned to the master scale for any reason, the actual weight of the car upon its arrival should be determined

and recorded. Any unusual variation between that weight and the nominal weight of the car should be promptly and fully investigated.

11. After the weight of the car on its arrival at the master scale has been determined, the car should receive any heavy repairs which are needed or may be needed before the next trip to the master scale, and should be thoroughly cleaned. At this time the axle bearings should receive any necessary lubrication and packing; after this has been done the car should be calibrated as outlined in paragraph 7 hereof.

[12]SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF MOTOR TRUCK, BUILT-IN, SELF-CONTAINED AND PORTABLE SCALES FOR RAILWAY SERVICE

INTRODUCTION

These specifications are intended to apply to knife-edge scales of the straight and torsion lever types equipped with beams for weighing less than carload freight. They do not apply to scales now in service, except that reinstallation of old scales should be governed as nearly as practicable by the provisions of the specifications relating to installation of new scales. They are intended, except in special cases, to secure a reasonable uniformity in scales for similar service, but without preventing improvements in types of scales or in scale parts. Requests for proposals for scales to conform to these specifications should specify the type and capacity of scale, and the size of the platform required, together with such other information as will insure complete and uniform proposals.

SECTION I—CAPACITIES AND SIZES

1. **Capacity Defined.**—The capacity of a scale is the weight of the heaviest load it will weigh under certain specified application of the load, without developing stresses in the members in excess of those hereinafter specified.

2. **Size Defined.**—The size of the scale is the width and length of platform on which the load is applied.

3. **Capacities and Sizes Standardized.**—The capacities and sizes of the different types of scales, except for special cases, shall be as follows, with the understanding that the term size has reference to the dimensions of the platform and that in stating these dimensions the dimension first given is that of the side adjacent to the beam:

(a) **Motor Truck Scales**

Capacity	*Sizes*
40,000 lb. (for 7½ Ton Trucks)	20′x9′, 22′x9′ and 24′x9′
30,000 lb. (for 5 Ton Trucks)	18′x9′ and 20′x9′
20,000 lb. (for 3½ Ton Trucks)	16′x8′ and 22′x8′

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[12] Adopted, Vol. 24, 1923, pp. 815, 1211; Vol. 28, 1927, pp. 613, 1409.

(b) **Built-In Scales**

Capacity	*Sizes*
5 Tons	6′x5′, 8′x6′ and 9′x7′
10 Tons	8′x6′ and 9′x7′

(c) **Self-Contained Scales**

Capacity	*Sizes*
2,500 lb.	46″x38″
4,000 lb.	48″x48″
10,000 lb.	72″x54″

(d) **Portable Scales**

Capacity	*Sizes*
1,000 lb.	18″x27″
2,000 lb.	25″x32″

4. **Corner and End Loading:**

(a) **Motor Truck Scales.**—They shall be designed for loads on any corner as follows:

> 20,000 lb. capacity scale, 75 per cent of the beam capacity; 30,000 lb. capacity scale, 65 per cent of the beam capacity; 40,000 lb. capacity scale, 62½ per cent of the beam capacity; and for all scales, 100 per cent of the beam capacity of the scale on either end. The above percentages of the capacity include the weight of the weighbridge and deck.

(b) **Built-In Scales.**—They shall be designed for 75 per cent of the rated capacity on any corner or 100 per cent of the rated capacity on any two corners together with the entire weight of the platform.

(c) **Self-Contained and Portable Scales.**—They shall be designed for 25 per cent of the rated capacity on any corner or 50 per cent of the rated capacity on any two corners together with the entire weight of the platform.

SECTION II—PLANS

1. For motor truck and built-in scales the manufacturer shall furnish to the purchaser plans showing the material of which the scale is to be fabricated, stresses, and sufficient dimensions to permit the purchaser to check the stresses; also assembly plans showing location and size of all open holes for field connections necessary for assembly and installation, and all information necessary for the purchaser to design and construct any pit or parts required and not designed or furnished by the scale manufacturer.

SECTION III—WORKING STRESSES

1. **General.**—The following unit stresses shall not be exceeded when the scale is loaded with its platform and to its capacity as defined above. These stresses include an allowance for impact.

2. Iron and Steel, Working Stresses in Pounds Per Square Inch.

Material	Transverse Bending		Direct Stresses		Shear and Torsion
	Tension	Compression	Tension	Compression	
Steel castings	8000	10000	8000	10000	5000
Machinery steel	12000	12000	12000	12000	7500
Structural steel	16000	16000	16000	16000	10000
Steel for pivots and bearings:					
High carbon	24000	24000	24000	24000	....
Special alloy	30000	30000	30000	30000	....
Cast iron:					
Thickness of section					
0.25″	5000	8500	3500	10000	5000
.3	4780	8130	3350	9560	4780
0.35	4600	7820	3220	9200	4600
0.4	4450	7560	3110	8900	4450
0.45	4320	7340	3020	8640	4320
0.5	4200	7140	2940	8400	4200
0.6	4020	6830	2814	8040	4020
0.7	3870	6580	2710	7740	3870
0.8	3740	6360	2620	7480	3740
0.9	3630	6170	2540	7260	3630
1.0	3540	6020	2480	7080	3540
1.1	3450	5860	2410	6900	3450
1.2	3380	5750	2370	6760	3380
1.3	3310	5620	2320	6620	3310
1.4	3250	5520	2270	6500	3250
1.5	3190	5420	2230	6380	3190
1.6	3140	5340	2200	6280	3140
1.8	3050	5180	2130	6100	3050
2.0	2970	5050	2080	5940	2970
2.5	2810	4780	1970	5620	2810
3.0	2690	4570	1880	5380	2690
3.5	2580	4390	1810	5160	2580
4.0	2500	4250	1750	5000	2500

The maximum allowable unit stress of any character used for designing cast iron members of a scale shall be determined for any section of such member by the greatest thickness used in the section, exclusive of fillets. In the main portion of a beam the thickness of the web or flange shall be used, whichever is the greater. The thickness of the flange shall be considered as either the average depth of the outstanding portion of the flange or the breadth of flange, out to out, whichever is the less.

The bearing stress on steel pins shall not exceed 15,000 lb. per square inch.

3. **Knife Edge Bearing Stresses.**—The load per linear inch of knife edge shall not exceed 5,000 lb.

4. **Concrete Bearing Stresses.**—Stresses to be allowed for bearing on concrete shall not exceed 300 lb. per square inch.

5. **Loops, Formula for Stresses.**—Considering the end of the loop as a simple beam, its section at the point of maximum bending shall be determined by the formula $\frac{W}{4}(L - \frac{1}{2}l)$ wherein W equals the maximum load applied to the loop, L equals the distance between the center lines of the depending sides, and l equals the distance over which the load is distributed.

6. **Projecting Pivots, Formula for Stresses.**—Where practicable, the pivots shall be supported their full length by integral parts of the lever.

Where impracticable to so support the pivots, the bending moments shall be determined as follows:

Let W = the total load on both ends of pivot, in pounds.
L = the moment arm, in inches.
l = the length of bearing in loop, in inches.
T = distance between friction faces of loop, in inches.
B = the width of boss or sustaining member enveloping pivot, in inches.
M = bending moment in pivot, in inch-pounds.

Then

$$L = \tfrac{1}{2}l + (T - B) + \tfrac{1}{4}\text{ inch}$$

and

$$M = \frac{WL}{2} = \frac{W}{2}\left(\tfrac{1}{4}l + (T - B) + \tfrac{1}{4}\text{ inch}\right).$$

7. **Tests.**—Before acceptance of a scale the purchaser may, if he so desires, test by customary approved methods any scale part or parts with a load equal to three times the rated capacity for the part, provided the manufacturer is given opportunity of having a representative present during the test, which shall be made within 60 days after delivery and before installation of the scale. Upon failure of any part so tested the purchaser may reject either the part or parts which failed or the entire scale and return same to the manufacturer at the latter's expense.

Section IV—Scale Levers

1. **Type.**—All levers of motor truck and built-in scales shall be of the solid lever type without truss rods.

2. **Qualities of Castings.**—The finished levers shall not be unduly warped; they shall be free from blisters, large holes or other imperfections, and shall be brought to a reasonably smooth finish.

3. **Machined Ways for Nose Irons.**—In motor truck scales, levers that are to be equipped with nose irons shall have those portions of the lever ends receiving them machined for the full distance over which the nose irons are to move.

The guides for all nose irons shall be of such construction that, when one is moved for the purpose of adjusting, the knife edge will always be held parallel to its normal position.

4. **Leveling Lugs.**—In motor truck scales and built-in scales of the straight lever type each lever shall be provided with leveling lugs for longitudinal alinement.

In scales of like classes of the torsion lever type, leveling lugs shall be provided on the pipe or torsion member for transverse alinement and on the extension arm for longitudinal alinement. Each pair of lugs shall be spaced 11 inches. The leveling surfaces of each pair of lugs shall be finished to a common plane which shall be parallel to the plane established by the knife edges of the end pivots.

5. **Marking of Levers.**—In motor truck and built-in scales figures denoting the multiple of each lever shall be cast or otherwise permanently marked in plain figures thereon.

6. **Length, Allowable Variation.**—In motor truck and built-in scales, levers shall be true to their nominal length between end knife edges within a tolerance of $\frac{1}{64}$ inch per foot.

Section V—Pivots and Knife Edges

1. **Material.**—In motor truck scales and built-in scales the requirements for physical properties of the steel used for pivots shall be as follows:

(a) Special Alloy Steel in the Annealed State:

Elastic limit	Not over 75,000 lb. per sq. in.
Tensile strength	Not over 110,000 lb. per sq. in.
Elongation in 2 in.	Not less than 20 per cent
Reduction in area	Not less than 35 per cent

(b) Special Alloy Steel Hardened:

Elastic limit	Not less than 160,000 lb. per sq. in.
Tensile strength	Not less than 200,000 lb. per sq. in.
Elongation in 2 in.	Not less than 5 per cent
Reduction in area	Not less than 25 per cent
Shore hardness	Not less than 75

(c) High Carbon Steel in the Annealed State:

Elastic limit	Not over 55,000 lb. per sq. in.
Tensile strength	Not over 117,000 lb. per sq. in.
Elongation in 2 in.	Not less than 15 per cent
Reduction in area	Not less than 25 per cent

(d) High Carbon Steel Hardened:

Elastic limit	Not less than 135,000 lb. per sq. in.
Tensile strength	Not less than 180,000 lb. per sq. in.
Elongation in 2 in.	Not less than 3 per cent
Reduction in area	Not less than 12 per cent
Shore hardness	Not less than 85

2. **Design.**—In motor truck scales and built-in scales all pivots shall be designed and manufactured so that the two sides joining to form the knife edge shall make an angle that will not exceed 90 degrees; that the tolerance for offset of the knife edge of the pivots, as figured from the center line of the pivot at its base, shall be within 10 per cent of the width of the pivot for "machined in" pivots, and 15 per cent of the width of the pivot for "cast-in" pivots.

3. **Mounting:**

(a) **Fastening.**—All pivots shall be firmly fastened in position, without swedging or caulking.

(b) **Continuous Contact.**—All pivots shall be mounted so as to secure equal and continuous contact of the knife edges with their respective bearings for the full length of the parts designed to be in contact; in loop bearings the knife edge shall project slightly beyond the bearings in the loops.

(c) **Position.**—The pivots shall be so mounted that each knife edge in a given lever will be maintained in a horizontal plane under any load; and so that a plane bisecting the angle of a knife edge will be perpendicular to the horizontal plane established by the knife edges of the end pivots, and so that the knife edges in a given lever will be parallel to each other.

4. **Support for Projecting Pivots.**—The reinforcing on the levers to support projecting pivots shall be tapered off to prevent lodgment of dirt next to the pivots and to provide proper clearances.

SECTION VI—NOSE IRONS

1. **Design and Fastening.**—The nose irons shall be firmly fastened in proper position by means of screws or bolts of a recognized standard size and thread, or other equally effective mechanical device.

(a) **Design of Fastening.**—The device for clamping the nose irons in position shall be of such design that indentations in the lever will not be made, and for motor truck scales and built-in-scales it shall be independent of any means provided for adjustment.

(b) **Direction of Fastening.**—For motor truck scales and built-in scales the device for clamping nose irons in position shall force or hold them against the lever in the same direction as they would be forced by the load, and shall be such that the nose irons will remain in place when the clamping device is released.

(c) **Control of Nose Iron Movement.**—The movement of the nose irons shall be controlled by means of adjusting screws of recognized standard size and thread. For motor truck scales these screws shall be made of a material which will not corrode.

2. **Marking of Position.**—The position of each nose iron as determined by the factory adjustment shall be accurately, clearly and permanently indicated by a well-defined mark on the lever and nose iron, which shall meet on a common line.

3. **Finish and Pivot Mounting.**—Those surfaces of the nose irons intended to come into slidable contact with the levers shall be made true so as to secure an accurate fit of the nose iron on or in the levers. Each nose iron shall be of such design that when adjustments are made the knife edge will be held parallel to its original position.

SECTION VII—LEVER FULCRUM STANDS

1. **Design:**

(a) **Height of Stands and Area of Bases.**—The height of the stands and the dimensions of their bases shall be sufficient to prevent tipping action.

(b) **Stands, Position on Bases.**—The upright portions of the stands carrying the bearings shall be so placed on the bases that the centers of the bearing lines shall fall within the middle of the length and of the width of the base.

(c) **Anchor Bolt Holes.**—One anchor bolt hole in the case of "A" lever scales, and two or more anchor bolt holes in the case of other scales, not less than 1½ inches in diameter, shall be provided in proper places in the bases of all the stands, unless other equally effective means for anchorage are provided.

2. **Qualities of Castings.**—The castings shall be free from blisters and large holes, or other imperfections, and shall be brought to a reasonably smooth finish.

3. **Bases for Lever Stands.**—The bases of the stands shall be finished to within a tolerance of 1/32 inch, or machined when to be mounted on metal bed plates, accurate to a plane perpendicular to the axis of the upright portion of the stand, and the knife-edge bearing line shall be parallel to the surface of the base.

4. **Stands, Finish of Tops.**—The tops of the stands for receiving the bearing steels, caps or blocks shall be finished to a tolerance of 1/32 inch.

5. **Tie Bars.**—Tie bars for the lever frames are not required, but if used, the contiguous surfaces shall be machined.

SECTION VIII—BEARING BLOCKS AND LINKS

1. **Material for Bearing Steels.**—The character of the material for bearing steels will be found under "Knife-Edges," Section V. The bearing steels shall be equal to or greater in hardness than the knife edges which oppose them.

2. **Design of Bearings.**—Scales shall be so designed that when the load is applied the movement of the platform will not displace the bearings at points of contact on the knife edges.

3. **Mounting of Bearing Steels.**—All like bearing steels shall be interchangeable or mounted in interchangeable bearing blocks. In either case the interchangeable part shall be fastened securely.

4. **Finish of Bearing Steels.**—The bearing surfaces shall be brought to a smooth, true and accurate finish to provide continuity of contact with the opposing knife edges.

5. **Platform Bearings.**—In motor truck scales and built-in scales the tops of platform bearings making contact with the weigh-bridge girders shall be finished to within 1/32 inch of a true plane. These tops shall be provided with bolt holes of a sufficiently large diameter to allow for adjustment both transversely and longitudinally to secure a proper alinement of parts.

SECTION IX—LOOPS AND CONNECTIONS

1. **Design Proportion.**—Loops which form bearings for projecting pivots may be of any type desired provided the radius of the portion of the bearing making immediate connection with the knife edges equals five-eighths of the greatest dimension of the cross-section of the pivot to be used in the loop.

2. **Length.**—All loops in like connections, except where made adjustable, shall be of the same length.

3. **Vertical Adjustment.**—Means for vertical adjustment shall be provided between the lever system and the beam, which shall permit the independent leveling of the shelf lever when one is used. The connection to the beam shall be adjustable only when it is disconnected. Screw adjustments shall be provided with lock nuts or equivalent device.

SECTION X—CHECKS

1. **Type.**—The weigh-bridges and platforms of all scales shall be equipped with checks of the rod or other approved type, which shall be equal to the rod type in functioning, and motor truck and built-in scales shall have adjustable checks.

2. **Character.**—Checks shall be provided to limit movement of weigh-bridge or platform in any horizontal direction.

3. **Position.**—The checks shall be attached to the weigh-bridge or platforms at a point as high as possible and shall be horizontal.

4. **Number.**—Motor truck and built-in scales using rod or bumper type of checks shall have not less than four longitudinal and four transverse checks. Those of the rod type shall be not less than ¾ inch in diameter and they shall be assumed to act in tension only.

SECTION XI—WEIGH BEAMS AND ACCESSORIES

1. **Definition of Capacity.**—The capacity of the beam is the total weight determinable by using all of the poises and counterpoise weights, provided, however, that a fractional poise may be ignored when it corresponds to less than 2½ per cent of the corresponding main beam.

2. **Capacity of Beams Provided:**

(a) **For Motor Truck Scales.**—For motor truck scales the capacity of the beam shall be as follows:

Truck Capacity Mfrs. Rating	*Beam Capacity*
3½ ton	20,000 lb.
5 ton	30,000 lb.
7½ ton	40,000 lb.

(b) **For Built-In, Self-Contained and Portable Scales.**—For built-in, self-contained and portable scales the capacity of the beam shall not exceed the rated capacity of the scales as provided for under Section I.

3. **Capacity Plainly Marked.**—The capacity of the scale as defined in Section I, Article 1, shall be marked plainly and conspicuously on or near the beam, in such a manner as to be readily and naturally observed by anyone using the scale.

4. **Type of Beam:**

(a) **Type of Beam for Motor Truck Scales.**—For motor truck scales a full capacity beam shall be provided. Registering beams shall be provided, if specified. When registering beams are used, tare beams shall not be provided unless specified. When tare beams are provided the graduation of main and fractional bars shall comply with the specification provided herein for the main beam.

(b) **Type of Beam for Built-In, Self-Contained and Portable Scales.**—Built-in scales shall be equipped with a full capacity beam with tare bar, or double beam with counterpoise weight, as may be specified.

Self-Contained scales shall be equipped with a double beam with counterpoise weights.

Portable scales shall be equipped with a single beam with counterpoise weights.

(c) On full capacity beams counterpoise hanger or weights shall not be used.

5. **Multiplication.**—A pivot with a loop shall be provided at the tip end of the beam, and the multiplication to this knife edge shall be plainly and permanently stamped on the beam and provided further that for beams with counterpoise weights the multiplication at the tip of the beam shall be as follows:

For built-in scales	500 or 1000
For self-contained scales	200 or 500
For portable scales	100

6. **Pointer.**—On motor truck scales the beam shall be provided with a pointer registering with a suitable and easily visible target on the trig loop to indicate the horizontal position of the beam.

7. **Shoulder Stop.**—A shoulder stop shall be provided on all beams to prevent the travel of the poise back of the zero notch.

8. **Notches.**—The number of notches for the main poise shall not exceed 6 per inch. Each notch shall be so made that when the pawl rests in it, a line projected from the center of the side of the notch nearer the zero graduation to the axis about which the pawl revolves will be perpendicular to that side of the notch.

9. **Pawl or Latch.**—The tip or point of the pawl or latch shall be of the same width as the notches of the beam, and shall be rounded off so that a small amount of dirt in the bottom of the notch will not prevent the poise from assuming its correct position.

10. **Projection and Recesses.**—Poises shall be designed so as to present the least number of recesses or projections in or on which dust or dirt may accumulate.

11. **Poise Bearings.**—Rollers or other means shall be provided to secure a free movement of the poise along the beam, without side play.

12. **Fractional Beam.**—The capacity of the fractional beam, on full capacity beams, shall be 100 lb. by 2 lb. graduations or 1000 lb. by 10 lb. graduations. When a type registering beam is employed it shall be so designed as to insure a positive stop of the poise at each graduated subdivision and also to prevent the movement of the fractional poise beyond its proper travel in either direction.

In type-registering beams, the last figure of the fractional beam shall read 999 lb. when the capacity of the fractional poise is 1000 lb. and 99 lb. when the capacity of the fractional poise is 100 lb.

13. **Operating Lever.**—On registering beams a substantial double or other approved type of hand grip shall be provided to facilitate the printing or registering of the weight on the ticket with the least possible disturbance of the beam.

14. **Receptacle for Weight Ticket.**—On registering beams means shall be provided to prevent the placing of the weight ticket in its receptacle in any position in which a weight can be registered differing from the setting of the poise.

15. **Balance Ball.**—For motor truck scales a balance ball shall be provided and its movement shall be controlled by means of a self-contained hand-operated screw or other device which will not require that the ball be rotated in making any adjustments. A means for locking the ball in position shall be provided. The balance ball shall be provided with vertical adjustment.

16. **Weight:**

(a) **Material.**—The poises and weights for the beam shall be made of steel, iron, brass or any other metal or alloy of metals not softer than brass.

(b) **Protection from Corrosion.**—Ordinary cast iron or steel weights shall be protected from corrosion by the application of a durable coating or process, which shall not take the form of a soft or brittle coat.

(c) **Surface and Form.**—The weights shall be smooth, without sharp points or corners, and of such form as to give the minimum wearing and exposed surface.

(d) **Adjusting Cavities.**—All cavities provided for the reception of adjusting material shall be formed in the top or sides of the counterpoise weights, and shall be of such a form that this material will be permanently and securely held in place. In no case shall this adjusting material project beyond the surface of the weight; and when in the top of the weight, in no case shall the top of the material closing the hole be more than 0.04 inch below the surface of the weight.

(e) **Poises.**—The poises which operate along the beam shall have no metal softer than brass making contact with the beam.

(f) **Movable Parts.**—All movable elements forming a part of a poise operated on the beam shall be constructed so as not to be readily detachable. Set screws, if used to secure the poise at any point on the beam, shall not be removable.

(g) **Marking.**—All counterpoise weights shall be clearly marked with their nominal weight, i. e., 1 lb., 2 lb., etc., as the case may be, and also with the value they represent when used upon the scale for which they are intended.

(h) **Sealing.**—After the weights are adjusted to their proper value, all caps or plugs closing adjusting cavities shall receive the impression of a seal, appropriate in character or design, to attest the factory adjustment, if made at the factory of the manufacturer; or, if readjusted elsewhere, the seal shall be such as to indicate where the adjustment was made.

(i) **Counterbalance Weights.**—If counterbalance weights are to be used, the lower end of the hanger stem shall be threaded; a cup for the loose balancing material shall be screwed to the lower end of the stem and each additional weight shall be provided with an elongated hole in the center through which the hanger stem may pass. No slotted counterbalance weights are to be used. When no counterbalance weights are necessary on top of the counterbalance cup the cavity shall be closed by a cover, secured in a positive manner. No counterbalance weights shall be used in any place in the scale except at the beam.

(j) **Tolerances.**—The maintenance tolerances to be allowed in excess or deficiency on commercial loose counterpoise weights shall not be greater than the values in the following table. The manufacturers' tolerances, or the tolerances to be allowed on new commercial weights and the tolerances which shall apply on readjusting the weights shall be not greater than one-half of the value tabulated.

17. **Identification of Parts.**—A serial number shall be stamped on the front of each complete beam.

On beams of motor truck scales identification marks shall be stamped on the pivots, poises and fractional bar, to show to which beam each belongs.

18. **Type Figures.**—On registering beams, type figures shall be made of a material sufficiently hard so that they will not easily become battered or defaced. The figures shall be plain and raised sufficiently high to insure a clear impression when the weight ticket or tape is stamped. They shall be so attached and secured in their proper place that they will not become loosened.

19. **Beam Fulcrum Stands.**—The relation of dimensions of the base to the height of all beam fulcrum stands shall be such as to prevent tipping action. A vertical line through the center of the pivot bearing line shall fall within the middle third of the bearing surface of the base.

AVOIRDUPOIS SYSTEM

Weight	Tolerance, Ordinary Weights	Tolerance, Counterpoise Weights for Multiplying-Lever Scales		
	(Ratio 1:1)	Ratio less than 100:1	Ratio 100:1 and less 1,000:1	Ratio 1,000:1 and over
Pounds	Grains	Grains	Grains	Grains
50	100.0	60.0	40.0	20.0
25	60.0	36.0	24.0	12.0
20	60.0	36.0	24.0	12.0
15	40.0	24.0	16.0	8.0
10	40,0	24.0	16.0	8.0
8	30.0	18.0	12.0	6.0
5	30.0	18.0	12.0	6.0
4	20.0	12.0	8.0	4.0
3	20.0	12.0	8.0	4.0
2	15.0	9.0	6.0	3.0
1	10.0	6.0	4.0	2.0
Ounces				
10	10.0	6.0	4.0	2.0
8	5.0	3.0	2.0	1.0
5	5.0	3.0	2.0	1.0
4	5.0	3.0	2.0	1.0
2	3.0	1.8	1.2	.6
1	2.0	1.2	.8	.4
½	2.0	1.2	.8	.4
¼	1.0	.6	.4	.2
⅛	.5	.3	.2	.1
1/16	.5	.3	.2	.1
1/32	.5	.3	.2	.1
1/64	.2	.12	.08	.04

For motor truck scales the beam shall be supported on a stand provided with compensating bearings and shall not be suspended.

20. **Trig Loops:**

(a) **Materials.**—When an iron or steel beam is used, the trig loop shall be made of a non-magnetic material.

(b) **Play of the Beam.**—The play of the beam in the trig loop shall not be less than that given in the following table:

*Length of Beam**	*Minimum Travel of Beam in Trig Loop*
Under 12 inches	0.4 In.
Over 12 inches, including 20 inches	.5 In.
Over 20 inches, including 40 inches	.7 In.
Over 40 inches	.9 In.

21. **Beam Support.**—A substantial and rigid beam shelf and support shall be provided. The beam fulcrum stand and the trig stand shall be securely fastened thereto. The shelf shall be strong and sufficiently rigid so that it will not deflect to an extent affecting the accuracy of the scale. For portable scales the design of the pillars shall provide ample rigidity.

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*The "Length of Beam" refers to the distance from the fulcrum to the trig loop.

SECTION XII—ANTI-FRICTION POINTS AND PLATES

1. Anti-friction contacts shall be used to limit longitudinal displacement between knife edges or pivots and their bearings. They shall be smooth and so designed as to provide contact at a point on the line of the knife edge of pivots; provided, that for motor truck and built-in scales they shall be of hardened steel.

SECTION XIII—CLEARANCES

1. The clearance around and between the fixed and live parts of the lever system of motor truck scales shall be at least ¾ inch, and for built-in and self-contained scales the clearance shall be not less than ⅜ inch. The total clearance between loops and stands shall be not less than ⅛ inch nor greater than ¼ inch.

SECTION XIV—FACTORY ADJUSTMENTS

1. **Levers.**—The design, workmanship and factory adjustment of the levers and beam shall be such that the proper ratio of the lever arms will be maintained.

2. **Beams.**—The notches in the beams shall be adjusted so that weights correct to within one-half the value of the minimum division will be obtained.

SECTION XV—INTERCHANGEABILITY

1. Like parts of all like motor truck and built-in scales of the same design and manufacture shall be interchangeable unless otherwise herein specified. The scale drawings and the parts of the scale shall be marked to indicate the proper positions of the parts in the scale.

SECTION XVI—SENSIBILITY RECIPROCAL

(Abbreviation "SR")

1. **Definition.**—The sensibility reciprocal shall be that weight required to be added to or removed from the scale platform to turn the beam from a horizontal position of equilbrium in the center of the trig loop to a position of equilibrium at either limit of its travel.

2. **Tolerance for Sensibility Reciprocal.**—The sensibility reciprocal for new scales shall not exceed the value indicated by one of the minimum divisions of the beam, at capacity or lesser load.

SECTION XVII—TOLERANCES

The tolerances to be allowed in excess or deficiency on motor truck built-in, self-contained and portable scales shall not be greater than the values shown in the following table; provided, however, that the manufacturer's tolerance or the tolerances on new scales shall not be greater than one-half the values given; and provided further, that the tolerances shall in no case be less than the value of one of the minimum graduations of the beam, except that the manufacturer's tolerances or the tolerances on new scales shall in no case be less than the value of one-half of one minimum graduations on the beam.

Load	Tolerance, Class A		Tolerance, Class B	
	On ratio	On beam	On ratio	On beam
Pounds	Ounces	Ounces	Ounces	Pounds
50	½	1	....	....
100	1	2	....	....
200	2	4	....	....
240	3	6	....	....
300	3	6	....	....
400	4	8	....	....
500	5	10	10	1¼
600	6	12	12	1½
		Pounds	Pounds	
800	8	1	1	2
1,000	8	1	1	2
1,200	10	1¼	1¼	2½
1,500	12	1½	1½	3
1,800	14	1¾	1¾	3½
	Pounds			
2,000	1	2	2	4
2,500	1¼	2½	2½	5
4,000	2	4	4	8
6,000	3	6	6	12
8,000	4	8	8	16
10,000	5	10	10	20
12,000	6	12	12	24
16,000	8	16	16	32
20,000	10	20	20	40
24,000	12	24	24	48
30,000	15	30	30	60
40,000	20	40	40	80
80,000	40	80	80	160
100,000	50	100	100	200
160,000	80	160	160	320
200,000	100	200	200	400
300,000	150	300	300	600
400,000	200	400	400	800

Definition of Terms Used in the Preceding Table.—"Class A" scales are those installed inside of a building having side walls and roof which protect the scale from weather effects and from sudden changes in temperature.

"Class B" scales are those not installed inside of a building having side walls and roof, and which are exposed to weather effects and sudden changes of temperature.

The columns with the heading "Tolerance on Ratio" refer to the error in the ratio or multiplying power of scales with which counterpoise weights are used.

The columns with the heading "Tolerance on Beam" refer to those parts of scales not requiring the use of removable weights; for example, a beam.

The column with the heading "Load" refers to the amount of weight on the platform of the scale.

SECTION XVIII—LOCATION AND ELEVATION

1. **Location.**—Motor truck, built-in and self-contained scales shall be so located that an adequate foundation and a straight approach in line with the scale platform and of a length in excess of that of the longest vehicle to be weighed can be provided.

2. **Elevation.**—The scale platform shall be raised to such an elevation that the drainage of surface water shall be away from it, and,

unless space will not permit it, the approaches shall be level, or nearly level and paved for a length equal to that of the scale platform.

SECTION XIX—FOUNDATIONS

1. **Material.**—Scale foundations resting upon or extending into the ground shall be constructed of concrete.

2. **Bearing Area.**—The bearing areas of the foundation footings shall be such that the bearing pressure on the soil, under the worst condition of loading, will not exceed

For fine sand or clay	4,000 lb. per sq. ft.
For coarse sand and gravel or hard clay	6,000 lb. per sq. ft.
For boulders or solid rock	20,000 lb. per sq. ft.

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity shall be increased, by drainage, by adding a layer of gravel or broken stone, or by driving piles.

3. **Dimensions of Pit.**—For motor truck and built-in scales the size of the pit shall be such as to give a vertical clearance between the scale levers and the finished floor of the pit of not less than 2 feet, and a horizontal clearance between the face of the pit walls and the scale parts below the platform, or below the weigh-bridge girders, if any, and above the bases of the stands, of not less than 4 inches for motor truck scales, and 1½ inches for built-in scales.

4. **Walls of Pit.**—The walls of the pit shall have a thickness at the top of not less than 12 inches for motor truck scales, and not less than 8 inches for built-in scales.

5. **Waterproofing.**—When necessary, the pit shall be waterproofed.

6. **Wall Batter.**—All wall surfaces next to earth, subject to freezing, shall be constructed with a uniform batter of not less than one inch to the foot, and as much more as necessary to permit the heaving of adjacent ground by frost action without disturbing the walls.

7. **Pit Floors and Lever Stand Piers.**—The concrete piers supporting the lever stands shall be not less than 9 inches deep, but shall in any case be carried to proper foundation. Their tops shall be above the floor of the pit a distance sufficient to prevent the accumulation of water under the bases of the stands, and they shall be finished to exact level and elevation to receive the lever stands. The floor of the pit may be designed as a mat footing of concrete, or as a simple floor not less than 4 inches thick. The pit floor shall, in all cases, be smooth, with a pitch to a common point of drainage and free from pockets in which water will stand. If the scale is of a type having main levers or parts of the platform bearings that hang below the base of the main lever stands, the piers shall be provided with recesses of a size to give a clearance of not less than 1½ inches and the recesses shall be formed to prevent lodgment of dirt.

8. **Anchor Bolts.**—Anchor bolts, not less than ⅞ inch in diameter, threaded and with nuts and washers, shall be provided in the founda-

tions for lever stands to match the bolt holes provided for securing the stands, and they shall extend into the concrete not less than 8 inches.

9. **Anchorage for Floating Levers.**—A floating lever, that is, one exerting an upward pull at its fulcrum, shall be anchored to the foundation to resist not less than twice the upward pull produced at the fulcrum pivot by a capacity load on the scale.

10. **Beam Foundations.**—The beam shelf and pillars shall be supported in a manner similar to and as securely and rigidly as the other parts of the scale.

Section XX—Scale Beam House or Box

1. **Scale Beam House or Box.**—When the scale is not located in a building the scale beam shelf shall be adequately protected from the weather by being enclosed in a house or box. When a scale is located in a building it shall, when necessary, be similarly protected from injury.

2. **Design.**—The minimum inside width of the scale house shall be 4 feet and the minimum length shall be sufficient to allow the installation therein of the beam shelf and beam. It shall be provided with windows of such size and location as will give the weigher, when weighing, a clear and unobstructed view of the scale deck and approaches. The windows shall be glazed with clear glass, or clear wire glass.

The scale beam box shall be of such size as to suitably enclose the beam shelf and beam. It shall be provided with a hinged door, or doors, of such size and in such location as to give the weigher clear and unobstructed access to the beam.

3. **Clearance.**—A clearance of not less than one inch shall be provided between the inside of the scale house and the beam supports and shelf.

For motor truck scales the lateral clearance between the outside wall of the scale house or beam box and the edge of the platform shall be not less than 2 ft. 6 in.

Section XXI—Setting of the Scales

1. **Fastening of Stands.**—After alining the stands the anchor bolt holes in the castings shall be filled with cement, sulphur or other suitable material and the anchor bolt nuts brought down tight.

2. **Alinement.**—All levers shall be level and connections plumb throughout the scale.

Section XXII—Platforms

(A) For Motor Truck and Built-in Scales

1. **Weigh Bridges:**

(a) **Material.**—Girders and floor beams shall be of steel conforming in quality with the American Railway Engineering Association Specifications for Steel Railway Bridges, Section 2

(b) **Sections and Strength.**—Sections of the various members of the weigh bridge shall be designed in accordance with Sections 4 and 5 of the American Railway Engineering Association Specifications for Steel Railway Bridges, except as the permissible working stresses are modified in Section III hereof.

(c) **Bracing.**—Weigh-bridges for built-in scales will usually require no bracing other than the floor beams and corner plates.

Weigh-bridges of motor truck scales with solid floor construction or with transverse floor beams, 3 foot centers or less, will require no lateral bracing, otherwise lateral bracing shall be provided for a lateral force of 100 lb. per linear foot plus 20 per cent of the sectional capacity, all applied laterally at the center of the span. The members of the lateral bracing shall be not less than 3" by 3" by ¼" angles.

Motor truck scale weigh-bridge girders shall be provided with end cross frames and at least one intermediate cross frame. These frames shall be preferably solid diaphrams, rolled or built up, and as deep as the girders will permit.

(d) **Fabrication and Assembly.**—The weigh-bridges for built-in scales shall be assembled and riveted or bolted up in the shop under proper inspection, so that they shall be square and free from wind when installed.

When practicable the weigh-bridges for motor truck scales shall be assembled and riveted up complete in the shop. When this method is impracticable and field assembling is necessary, the parts shall be properly assembled in the shop and match marked and have connecting holes reamed to fit.

2. **Deck:**

(a) **Design.**—The floor shall be designed so that without exceeding the permissible stresses it will support and distribute the rated capacity load when applied in a manner to produce the maximum stress in any part of the floor.

(b) **Flooring.**—The flooring shall be of such material as will resist wear and abrasion, will not present a slippery surface and which can be waterproofed. If timber is used it should be creosoted or treated with some other wood preservative. Where the floor consists of a subfloor and wearing surface a steel facing or retaining strip, such as an angle, shall be attached along the sides and ends of the deck.

(B) For Self-Contained and Portable Scales

3. **Material and Design.**—The platform shall be entirely of metal or a metal frame, with a hardwood center panel and shall be so designed that, without exceeding the permissible stresses, it will support and distribute the rated capacity load when applied in a manner to produce the maximum stress in any part of the platform.

SECTION XXIII—APPROACHES

1. Wherever possible the approaches shall be straight and level or nearly level, in line with the scale platform, and paved for a length at least equal to the scale platform.

Section XXIV—Light, Drainage and Ventilation

1. **Light.**—Proper lighting of the scale weighing beam and scale platform shall be provided.

2. **Drainage.**—Adequate drainage for scale pits shall be provided and maintained.

3. **Ventilation.**—All scale pits shall be ventilated to meet the needs of each particular case, the object being to minimize the amount of moisture in the air in the pit and so to retard rusting of scale parts and structural steel.

Section XXV—Entrance to Scale Pit

1. **Location.**—For the built-in scales, the entrance to the scale pit for inspection purposes shall be through the platform of the scale, foundation wall, or the neck of the scale pit, and shall be closed by a suitable door; for motor truck scales, the entrance to the scale pit shall be through the foundation wall or neck of the pit.

Section XXVI—Protection From Corrosion

1. **Shop Painting.**—When no shop inspection is provided, or after shop inspection when it is provided, all parts of the mechanism and structural steel of motor truck and built-in scales shall be given one coat of red lead and linseed oil and all parts of the mechanism of self-contained and portable scales shall be given two coats and the inside of the platform and the frame one coat of paint.

In riveted work, surfaces coming in contact shall be given one coat of red lead paint before being riveted together. All parts of motor truck and built-in scales which are inaccessible after erection shall be given a second shop coat of red lead paint.

2. **Field Painting.**—All parts of the scale mechanism and structural steel of motor truck and built-in scales shall be cleaned and painted with one coat (and preferably two coats) of approved paint in the field before installation.

[13]SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF TWO-SECTION KNIFE-EDGE RAILWAY TRACK SCALES

Introduction

These specifications are intended to cover two-section knife-edge track scales for weighing cars in railway service without the use of dead rails or relieving gear. They do not cover overhead suspended scales, nor do they apply to scales already in service, except that reinstallations of old scales should conform as nearly as practicable to the provisions herein relating to the installation of scales and to pivots and bearing steels. They are intended, except for special cases, to result in reasonable uniformity of scales for similar service, but without preventing or discouraging improvements in types of scales or in scale parts.

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[13] **Adopted, Vol. 28, pp. 593, 1410.**

Requests for proposals for track scales conforming to these specifications should specify the class or sectional capacity, and length of scale required, together with such other information as will insure complete and uniform proposals.

SECTION I—CLASSES OF SCALES

1. **Character of Classification.**—Scales shall be classified into two capacities, namely, 200-ton per section scales and 150-ton per section scales. These specifications apply to both classes of scales except when otherwise specifically provided herein.

2. **200-Ton Per Section Scales.**—200-ton per section scales are to be selected for typical railway and heavy industrial installations. They shall have lengths of either 60 ft. or 75 ft. 60-foot scales may be used for motion weighing of cars whose wheel-base does not exceed 41 feet. 75-foot scales may be used for motion weighing of cars whose wheelbase does not exceed 51 feet.

3. **150-Ton Per Section Scales.**—150-ton per section scales are to be selected for points where the scale track traffic will be relatively light. They shall have lengths of either 50 feet or 60 feet. 150-ton per section scales are not recommended for motion weighing.

4. **Special Cases.**—For special cases, which cannot be covered by these specifications, it is recommended that all features of the scales be at least equal to those prescribed herein, and that the principles herein embodied be followed, in so far as they apply.

SECTION II—CAPACITY

1. **Capacity Defined.**—The capacity of a two-section track scale is the weight of the heaviest locomotive that will pass over the scale rails without developing in any member stresses in excess of those hereinafter specified.

2. **Capacity Required.**—The capacity of the scale shall suffice to meet the requirements of these specifications under the heaviest loading to which the scale may be subjected.

3. **Sectional Capacity.**—The sectional capacity of a scale is the greatest weight which may be divided equally on the load pivots of each pair of main levers without producing stresses in any scale member in excess of those hereinafter specified.

SECTION III—PLANS

On request the manufacturer shall furnish to the purchaser plans of design, showing stresses and detailed dimensions for all scale parts, and the material of which they are to be made. Assembly plans shall also be furnished showing the location of field connections and all information necessary for the purchaser to design and construct the pit and parts not furnished by the manufacturer.

Section IV—Working Stresses

1. **General.**—The following unit stresses shall not be exceeded when the scale is loaded to its capacity as defined above. These stresses include an allowance for impact caused by moving loads. The strength of each member shall be determined from its weakest cross-section.

2. **Iron and Steel; Working Stresses in Pounds Per Square Inch.**—

	Cast Iron	*Steel Castings*	*Machinery Steel*	*Structural Steel*	*Special Alloy Steel for Pivots and Bearings*
Tension	2,000	8,000	12,000	See Section XXIV	30,000
Compression	8,000	10,000	12,000		30,000
Transverse Bending Tension	2,500	8,000	12,000		30,000
Transverse Bending Compression	4,000	10,000	12,000		30,000
Shear	2,500	6,000	7,500		
Torsion	2,500	6,000			

High Carbon Steel not to be used for pivots and bearings.

3. **Steel Pins.**—The bearing stress on steel pins shall not exceed 15,000 lb. per sq. in. on any diametral cross-section.

4. **Knife-Edge Bearing Stresses.**—The load per linear inch of contact between knife-edges and their opposing bearings shall not exceed 6000 lb.

5. **Concrete Bearing Stresses.**—Bearing stresses on concrete shall not exceed 300 lb. per square inch under scale lever stands, and 400 lb. per square inch at all other points.

6. **Loops—Formula for Stresses.**—Considering the end of the loop as a simple beam, its section at the point of maximum stress shall be determined from the formula $\frac{W}{4}\left(L - \frac{d}{2}\right)$, in which W is the maximum load applied to the loop, L is the distance between the center lines of the depending sides, and d is the distance over which the load is distributed.

7. **Projecting Pivots—Formula for Stresses.**—Where practicable, pivots shall be supported their full length by integral parts of the lever containing them. Where pivots cannot be so supported, bending moments in the pivots shall be determined as follows:

Let W = the total load on both ends of the pivot in pounds.
L = the moment arm in inches.
d = the length of bearing in the loop in inches.
T = the distance between friction faces of the loop in inches.
B = the width of boss or sustaining member enveloping the member in inches.
M = the bending moment in the pivot in inch-pounds.

Then $L = \frac{1}{2}d + (T-B) + \frac{1}{4}$ inch
and $M = WL/2$.

SECTION V—LENGTH OF SCALE

1. **Scale Length Defined.**—The length of a track scale is the length of the live rail. The live rail shall not project over the ends of the weigh-bridge girders.

2. **Limits of Overhang.**—The scale may be longer than the distance between its sections. In no case, however, shall the distance from the center of a section to the nearer end of the live rails exceed three feet.

SECTION VI—SCALE LEVERS

1. **Quality of Castings.**—Castings for use in scales shall not be unduly warped. They shall be clean, smooth, uniform, and free from blisters, blowholes and shrinkage cracks.

2. **Machined Ways for Nose Irons.**—That portion of any lever that is to be fitted with a nose iron shall be machined for the full distance over which the nose iron is to move.

3. **Leveling Lugs.**—Each lever shall be provided with leveling lugs. Each pair of lugs shall be spaced 11 inches, center to center. The leveling surface of each pair of lugs shall be finished to a common plane parallel to the plane through the knife edges of the end pivots.

4. **Marking of Levers.**—The multiple shall be permanently and legibly marked on each scale lever.

5. **Length—Allowable Variation.**—The lengths of main and extension levers shall conform to their nominal lengths between end knife-edges within ⅛ inch and ¼ inch, respectively.

6. **Loading of Levers Other Than Main Levers.**—In designing levers other than main levers, it shall be assumed that each longitudinal extension lever carries an applied load corresponding to 100 per cent of the sectional capacity, and that the transverse extension lever carries an applied load corresponding to 200 per cent of the sectional capacity.

SECTION VII—PIVOTS AND KNIFE-EDGES

1. **Material.**—The requirements for physical properties of steel used for pivots and bearing steels shall be as follows:

(a) Special Alloy Steel—annealed:

Elastic limit..........	Not over 75,000 lb. per sq. in.
Tensile strength.......	Not over 110,000 lb. per sq. in.
Elongation in 2 inches.	Not less than 20 per cent.
Reduction in area......	Not less than 35 per cent.

(b) Special Alloy Steel—hardened:

Elastic limit..........	Not less than 160,000 lb. per sq. in.
Tensile strength.......	Not less than 200,000 lb. per sq. in.
Elongation in 2 inches.	Not less than 5 per cent.
Reduction in area......	Not less than 25 per cent.
Shore hardness.........	Not less than 75.

2. **Design and Manufacture.**—Pivots shall be so designed and manufactured that the included angle of the sides forming the knife edge will not exceed 90 degrees, and the offset of the knife edge, as

referred to the vertical center line through the base of the pivot, will not exceed 10 per cent of the width of the pivot. Knife edges shall be straight within a tolerance of 0.0002 inch per inch of length of pivot.

3. **Mounting:**
   - (a) Pivots shall be firmly fastened in position without swedging or caulking.
   - (b) Pivots in main and extension levers shall be fitted into machined ways.
   - (c) Pivots shall be so mounted that the knife edges make contact with their opposing bearings throughout the length of the parts designed to be in contact within the limits specified above. The length of each end of projecting knife edges intended to engage loop bearings shall exceed the length of the bearing in each side of the loop by an amount equal at least to the total clearance between the lever and the loop.
   - (d) In any lever the pivots shall be so mounted that:
     - (1) Each knife edge in any lever will be maintained in a horizontal plane under any load within the capacity of the scale.
     - (2) A plane bisecting the angle of a knife edge will be perpendicular to the plane through the knife edges of the end pivots.
     - (3) The knife edges in any lever will be parallel to each other.

4. **Support for Projecting Pivots.**—The reinforcing on the levers to support projecting pivots shall be tapered off to prevent lodgment of dirt next to the pivots and to provide proper clearances.

5. **Fulcrum Distances.**—The distance between knife edges of fulcrum and load pivots of main levers shall be not less than eight inches.

SECTION VIII—NOSE IRONS

1. **Design and Fastening.**—The nose irons shall be firmly fastened in proper position by means of U.S. standard thread screws or bolts, or other equally effective mechanical device.
   - (a) Design of Fastening.—The means for clamping the nose irons in position shall be of such design that indentations in the lever will not be made, and shall be independent of any means provided for adjustment.
   - (b) Direction of Fastening.—The means for clamping nose irons in position shall force or hold them against the lever in the same direction as they would be forced by the load.
   - (c) Control of Nose Iron Movement.—The movement of the nose irons shall be controlled by means of adjusting screws of U.S. standard thread. These screws shall be made of a material which will not corrode.

2. **Marking of Position.**—The position of each nose iron as determined by the factory adjustment shall be accurately, clearly and permanently indicated by a well defined mark on the lever and nose iron, which shall meet on a common line.

3. **Finish and Pivot Mounting.**—Nose iron surfaces intended to be in slidable contact with levers shall be made true in order to secure an accurate fit on or in the levers. Nose irons and guides shall be of such construction that, when a nose iron is moved through any portion of its allowable travel, the knife edge will be held parallel to its normal position.

SECTION IX—LEVER FULCRUM STANDS

1. **Design:**
   (a) Pillars—Position on Bases.—The pillars or upright portions of the stands carrying the bearings shall be so placed on the bases that the centers of the bearing lines will be over the centers of gravity of the bearing surfaces of the stands.
   (b) Height of Pillars.—In stands of the two-pillar type, the pillars shall be of equal height.
   (c) Anchor Bolt Holes.—Four or more anchor bolt holes, not less than two inches in diameter, shall be provided in proper places in the base of each stand, unless other equally effective means for anchorage are provided.

2. **Quality of Castings.**—Castings for lever stands shall be clean, smooth, uniform, and free from blisters, blowholes and shrinkage cracks.

3. **Finish of Bases.**—The base of each stand shall be machined to a plane perpendicular to the upright axis through the center of the knife edge bearing line.

4. **Finish of Pillar Tops.**—The tops of pillars for receiving bearing steels, caps or blocks, shall be finished so that the knife edge bearing line will be parallel to the machined surface of the base of the stand within 1/32 inch.

5. **Tie Bars.**—When tie bars for lever frames are used, contiguous surfaces shall be machined.

SECTION X—BEARINGS AND BEARING BLOCKS

1. **Material for Bearing Steels.**—The requirements for physical properties of steel used for bearings shall be the same as those set forth in Section VII-1 hereof for pivots.

2. **Design of Bearings.**—Bearings shall be so designed that displacement of the line of contact between a bearing and its opposing knife edge will not occur under practical conditions of loading.

3. **Mounting of Bearing Steels.**—All like bearing steels shall be interchangeable or mounted in interchangeable bearing steel blocks. When bearing steels are separable and interchangeable, they shall be fastened in position by U.S. standard thread set screws, of a non-

corrosive material at least as hard as brass, or by other equally effective mechanical device.

4. **Finish of Bearing Steels.**—The bearing surfaces shall be brought to a smooth, true and accurate finish to provide continuity of contact with the opposing knife edges within a tolerance of 0.0002 inch per inch of length of pivot.

5. **Weigh-Bridge Bearings.**—The surfaces of weigh-bridge bearings intended to make contact with the bridge girders shall be finished so that, when in position, all the bearing surfaces will be within 1/32 inch of the same horizontal plane and parallel to it. To secure proper alinement of parts, the diameter of the bolt holes in the weigh-bridge bearings and in the girders shall exceed the diameter of the bolts fastening the bearings to the girders by ½ inch, to allow for necessary transverse and longitudinal adjustment.

Section XI—Loops and Connections

1. **Material.**—The requirements for material and hardness of bearing surfaces in loop connections shall be the same as those herein prescribed for pivots and bearings.

2. **Design.**—In loops which form bearings for projecting pivots, the radius of the portion of the bearing making immediate contact with the knife edge and the radius of the eye of the loop shall be not less than the longest side of the cross-section of the square pivot to be used in the loop, and like clearance shall be provided if pivots of other than square cross-section be used.

3. **Length.**—Loops in like connections, except when adjustable, shall be of the same length.

4. **Steelyard Rod.**—The steelyard rod shall be equipped with a turnbuckle.

5. **Locknuts.**—Bolts or turnbuckles used as parts of the connections shall be provided with locknuts.

Section XII—Checks

1. **Type.**—Weigh-bridge checks shall be provided, and shall be of the rod or other type which shall be equal to the rod type in functioning. Checks of the rod or bumper type shall be adjustable.

2. **Character.**—Both longitudinal and transverse checks shall be provided.

3. **Number.**—Not less than four longitudinal and four transverse checks shall be provided.

4. **Position.**—Checks shall be set as high as possible, and shall be in the same horizontal plane. Longitudinal and transverse checks shall be, respectively, parallel and perpendicular to a vertical plane through the center line of the track.

5. **Strength.**—Checks of the rod type shall be considered to act only in tension. The combined checks at either end or side shall be designed to resist a force of 66,000 lb.

SECTION XIII—WEIGH-BEAM AND ACCESSORIES

1. **Design:**

   (a) Capacity.—For 200-ton per section scales, a direct reading capacity of 335,000 lb. shall be provided, and in addition, when desired, a non-registering tip weight representing 200,000 lb. may also be provided. For 150-ton per section scales, a direct reading capacity of 250,000 lb. shall be provided, and in addition, when desired, a non-registering tip weight representing 150,000 lb. may also be provided.

   (b) Shoulder Stop.—A shoulder stop shall be provided on all beams to prevent the travel of the main poise back of the zero notch.

   (c) Notches.—The number of notches for the main poise shall not exceed six per inch. Each notch shall be so made that when the pawl rests in it, a line projected from the center of the side of the notch nearer the zero graduation to the axis about which the pawl revolves will be perpendicular to that side of the notch.

   (d) Pawl or Latch.—The tip or point of the pawl or latch shall be of the same width as the notches of the beam, and shall be rounded off so that a small amount of dust or dirt in the bottom of the notch will not prevent the poise from assuming its correct position.

   (e) Projections and Recesses.—Poises shall be so designed as to present the least number of recesses or projections in or on which dust or dirt may accumulate.

   (f) Ball or Cone Bearings.—Ball bearings, cone bearings or other means shall be provided to secure as free movement of the poise along the beam as possible, but without side play of the poise.

   (g) Registering Beams.—Scales that are to be used exclusively for spot weighing may be equipped with registering beams.

   (h) Fractional Bar Stops.—On registering beams the fractional poise shall be equipped with means to insure a positive stop at any 20-lb. interval, and a stop shall be provided to prevent the movement of the fractional bar beyond its proper travel in either direction.

   (i) Operating Lever.—A substantial double or other approved type of hand grip shall be provided to facilitate the printing or registering of the weight on the ticket with the least possible disturbance of the beam.

   (j) Receptacle for Weight Ticket.—On registering beams means shall be provided to prevent the placing of the weight ticket in its receptacle in any position in which an incorrect weight can be registered.

2. **Marking:**

   (a) Intervals.—The notches and graduations on the main beam shall be made at the 1000 lb. intervals.

(b) Length of Graduations.—For the main beam, the zero graduation and all graduations representing multiples of 10,000 lb. shall be ¾ inch in length. All graduations having values in thousands of pounds ending in 4 and 8 shall be ½ inch in length. All other graduations shall be ¼ inch in length. An alternative method of marking may be used in which the marks representing 5, 15, 25, etc., thousand pounds shall be not less than 1½ times the intermediate lines, and every tenth line shall be longer than every fifth line, and the length of the graduations other than the fives and tens shall be not greater than twice the distance between their centers, preferably 1½ times the distance between their centers.

(c) Size of Figures.—For the main beam, the zero graduation and every tenth graduation therefrom shall have its value in thousands of pounds (i.e., 0, 10, 20, etc.) marked by figures ⅜ inch in height, except the last graduation on the beam, which shall be marked in full—for example, 250,000 lb. All other graduations in beams graduated by the first method, having values in thousands of pounds ending in an even figure, namely, 2, 4, 6 and 8, shall be marked by figures 3/16 inch in height. On beams graduated by the second method, the fives, fifteens, etc., may or may not have the value in thousands of pounds marked, or may have a star or other device placed opposite the line. No other graduations having readings in thousands of pounds ending in an uneven figure shall be marked. All numbers shall be placed directly beneath their respective graduations, and shall be within 1/16 to ⅛ inch of the graduation.

(d) Fractional Beam.—For registering beams, the graduations for the fractional beam shall be placed at 20-lb. intervals up to and including 980 lb., or, if the fractional beam corresponds to a full 1000 lb., the last figure shall be marked to read 999 lb. Non-registering fractional beams shall be graduated in 50-lb. intervals, except for special cases.

3. **Balance Ball.**—A balance ball shall be provided. If it be a rotating ball, its center of gravity shall lie in the axis of rotation. Otherwise its movement shall be controlled by means of a self-contained hand operated screw or other device which will not require that the ball be rotated in making any adjustments. Means for locking the ball in position shall be provided. The balance ball shall be provided with vertical adjustment.

4. **Counterbalance Weights.**—If counterbalance weights are to be used, the lower end of the hanger stem shall be threaded; a cup for the loose balancing material shall be screwed to the lower end of the stem, and each additional weight shall be provided with an elongated hole in the center through which the hanger stem may pass. No slotted

counterbalance weights are to be used. When no counterbalance weights are necessary on top of the counterbalance cup, the cavity shall be closed by a cover, secured in a positive manner. No counterbalance weights shall be used in any place in the scale except at the beam.

5. **Multiplication.**—A pivot with a loop shall be provided at the tip of the beam. The multiplication to this pivot knife edge shall be 7000 or 10,000, or multiples thereof, and shall be plainly and permanently stamped on the beam.

6. **Identification of Parts.**—Each beam shall be given a serial number, which shall be stamped on the beam. The pivots, poises, and fractional bar shall have stamped on them identification marks to show to which beam each belongs, and the pivots shall be so marked as to indicate their proper positions in the beam.

7. **Type Figures.**—Type figures shall be made of a material sufficiently hard so that they will not easily become battered or defaced. The figures shall be plain and raised sufficiently high to insure a clear impression when the weight ticket or tape is stamped. They shall be so attached and secured in their proper places that they will not become loosened.

8. **Beam Fulcrum Stand:**

   (a) Design.—The beam shall be supported on a stand provided with compensating bearings, and shall not be suspended. The height of the pillars and the dimensions of the base of the stand shall be such as to prevent a tipping action.

   (b) Height.—The height of the stand, measured from the bottom surface of the base to the pivot bearing surface, shall not exceed 13 inches.

   (c) Finish.—The bearing surface of the base of the stand shall be finished to a plane perpendicular to the axis of the upright portion of the stand, and the knife-edge line of the bearing shall be parallel to the base. The center of the bearing line shall be vertically over the center of gravity of the bearing surface of the base.

9. **Trig Loop:**

   (a) Material.—The contact parts of the trig loop shall be made of a non-magnetic material.

   (b) Play of the Beam.—The play of the beam in the trig loop shall be not more than two per cent of the distance from the trig loop to the knife edge of the fulcrum pivot.

   (c) Pointer.—The beam shall be fitted with a pointer to be used in connection with a fixed graduation or other device on the trig loop to indicate a central position in the trig loop when the beam is horizontal.

10. **Beam Support.**—Cast iron pillars, or equivalent, and a beam shelf shall be provided for all scales. The beam fulcrum and the trig

stand shall be securely erected thereon. This shelf shall be strong and sufficiently rigid so that it will not deflect to an extent that the action of the scale will be affected.

SECTION XIV—ANTIFRICTION POINTS AND PLATES

1. **Required.**—Antifriction points and plates shall be provided to limit the relative lengthwise displacement of all knife edges with respect to their bearings.

2. **Material.**—The antifriction points and plates shall be made of hardened carbon steel, and the plates shall be at least as hard as the points which come in contact with them.

3. **Design.**—The antifriction points shall consist of a point or projection of small area formed on the knife edge in the case of full-length contact knife edges, or shall be formed on plates securely attached to the levers or pivots. The design of the antifriction points shall be such that they will always make contact with their opposing plates on the line of the knife edges, within practical limits. In loop bearings the parts which come in contact with the antifriction points shall be formed without any points or projections so that, when the loop is relatively displayed in a direction at right angles to the knife edges, the contact will continue to be made with the antifriction points on the line of the knife edge.

4. **Clearances.**—The clearances between the antifriction plates and antifriction points shall not exceed 1/16 inch on the beam, 1/8 inch on the shelf lever, and 1/4 inch on all other levers, and the minimum clearances shall not be less than one-half these amounts, respectively.

SECTION XV—CLEARANCES

The clearance around and between the fixed and live parts of the lever system of a scale shall be at least 3/4 inch, except at points where other clearances are specified.

SECTION XVI—FACTORY ADJUSTMENTS

1. **Levers.**—The design, workmanship, and factory adjustment of the levers and beam shall be such that the proper ratio of the lever arms will be maintained.

2. **Beams.**—Each notch in the beam shall be adjusted to within 0.002 inch of the nominal distance from the zero notch.

SECTION XVII—INTERCHANGEABILITY

Like parts of all like scales of the same design and manufacture shall be interchangeable, unless otherwise herein specified. The scale drawings and the parts of the scale shall be marked to indicate the proper positions of the parts in the scale, so as to prevent parts not symmetrically designed being incorrectly placed when the scale is set up.

SECTION XVIII—SENSIBILITY RECIPROCAL

1. **Definition.**—The sensibility reciprocal shall be that weight required to be added to or removed from the live rails to turn the beam from a horizontal position of equilibrium in the center of the trig loop to a position of equilibrium at either limit of its travel.

2. **Value.**—The sensibility reciprocal shall not exceed 50 lb. in any case.

SECTION XIX—TOLERANCE

The manufacturer's tolerance to be allowed on the first field test, after the installation corrections, of all new railway track scales shall not exceed 1/20 of 1 per cent, or 50 lb. per 100,000 lb., for any position of the test car load on the scale. The minimum test car load to be applied shall be 30,000 lb.

SECTION XX—LOCATION AND ELEVATION

1. **Foundation.**—Scales shall be so located that an adequate foundation, and at least 50 feet of tangent track at each approach to the scale rails, can be provided.

2. **Elevation.**—The scale shall be raised with respect to the other tracks of the yard to such an elevation that the drainage of the surface water will be away from it. Means shall be provided to prevent surface water between the rails of the scale track from running into the pit.

3. **Right-Handed Beam.**—Scales shall be so located that a right-handed beam can be used in all cases without the use of extension levers, exclusive of shelf lever, between transverse extension lever and beam.

SECTION XXI—FOUNDATIONS

1. **Material.**—All scale foundations shall be constructed of concrete. The quality of the materials and the methods of mixing and placing the concrete shall be in accordance with the railway's specifications for first-class concrete, or other first-class engineering practice may be followed.

2. **Bearing Area.**—The bearing areas of the foundation footings shall be such that the bearing pressure on the soil will be uniform throughout and not exceed:

	Lb. per sq. ft
For fine sand or clay	4,000
For coarse sand and gravel, or hard clay	6,000
For boulders or solid rock	20,000

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity should be increased by drainage, by adding a layer of gravel or broken stone, or by driving piles.

3. **Dimensions of Pit.**—The depth of the scale pit shall be not less than 7 feet from the base of the rail to the finished floor of the pit. The width of the pit between faces of side walls shall be not

less than 10 feet, provided that there shall be a horizontal clearance of not less than 16 inches between the faces of the side walls and the scale parts below the weigh-bridge girders and above the bases of the stands. The length of the pit inside of the end walls shall be not less than 2 feet greater than the length of the scale parts.

4. **Walls of Pit.**—The side and end walls shall be not less than 15 inches, and preferably 18 inches, thick at the top. The foundation walls of the scale house shall be not less than 12 inches thick at the top, and shall be formed solidly to the side walls of the scale pit.

5. **Waterproofing.**—Where necessary to prevent seepage of water through foundations into the scale pit, they shall be waterproofed and drained into a waterproof cistern located outside the scale pit and equipped with either pump, siphon, or automatic "cellar drainer."

6. **Approach Walls.**—Approach walls or piers of concrete shall be built to extend at least 15 feet, preferably 25 feet, from the pit face of the end wall at the approach and back under the track, to preserve line and surface of the approach tracks. They may be built in one solid mass of concrete, or they may consist of two parallel walls or piers, but with either type of construction they shall have a single foundation footing. Where necessary to secure safe bearing capacity, they shall be carried to the same depth as the pit walls.

7. **Wall Batter.**—All wall surfaces next to earth subject to freezing shall be constructed with a uniform batter of not less than 1 inch to the foot, and as much more as necessary to permit the heaving of adjacent ground by frost action without disturbing the walls.

8. **Footings or Piers for Lever Stands.**—The concrete footings or piers supporting the lever stands shall be not less than 18 inches thick. Their tops shall be above the floor of the pit a distance sufficient to prevent the accumulation of water under the bases of the stands, and they shall be finished to exact level and elevation to receive the lever stands directly without the use of shims or grouting. The floor of the pit may be a solid mat of concrete nearly the same thickness as that required to support the lever stands, or it may be not less than 6 inches thick where local conditions permit. The pit floor shall in all cases be smooth and with a pitch to a common point of drainage and free from pockets in which water will stand. If the scale is of a type having main levers or parts of the platform bearings that hang below the bases of the main lever stands, the piers shall be provided with recesses of a size to give a clearance of not less than 1½ inches, and the recesses shall be formed to prevent lodgment of dirt.

9. **Anchor Bolts.**—Anchor bolts shall be provided in foundations for lever stands to match the bolt holes provided for securing the stands, and they shall extend into the concrete not less than 15 inches.

10. **Anchorage for Floating Levers.**—Floating levers, viz., levers exerting an upward pull at their fulcrums, shall be anchored to the foundation to resist not less than twice the uplift produced by the combined dead load and capacity live load.

11. **Deck Beam Supports.**—Inverted "T" rails, or bearings of steel, shall be set in the side walls of the pit with the center of bearings not less than 6 inches from the inside face of the walls, but such bearings shall not be fastened to transverse beams.

12. **Beam Foundations.**—The pillars supporting the beam shelf shall rest upon a reinforced concrete floor, steel beams, or reinforced concrete beams, but the pillars and supporting beams, if used, shall be independent of the scale house floor, if of timber construction. When it is necessary to install the scale beam in any building other than a regulation scale house, the pillar supports shall rest on foundations independent of the building unless the foundation of the building is free from vibrations and settlement.

13. **Safety Piers.**—Suitable piers, columns, or other supports should be provided to prevent excessive drop of the girders should failure of the scale parts occur.

SECTION XXII—SCALE BEAM HOUSE

1. **Design.**—The minimum inside width of the scale house shall be 4 feet, and the minimum length shall be sufficient to allow the installation therein of a full-size beam shelf and regulation beam of proper capacity for the scale, and self-recording attachment if used. It shall be provided with a bay window, or front and end windows, located with their sills about on a level with the top of the beam shelf, and of sufficient size to give the weigher a clear and unobstructed view of the scale deck and approaching cars, so that he can read the car numbers and stenciled light weights when he is weighing. The windows shall be glazed with clear glass, or clear wired glass, free from bubbles or other imperfections.

2. **Clearances.**—The lateral clearance between the scale house and the center of any track shall be not less than 7 feet 6 inches, or greater if required by law or by the railway. A clearance of not less than 1 inch shall be provided between the inside of the scale house and the beam supports and shelf.

3. **Ventilation.**—Where a scale beam house is not provided with artificial heat, a ventilator in the roof shall be provided.

SECTION XXIII—SETTING OF THE SCALE

1. **Fastening of Stands.**—After alining the stands, large washers shall be applied to the anchor bolts, and the nuts brought down tight. The anchor bolt holes in the castings shall then be filled with cement, sulphur, or other suitable material.

2. **Alinement.**—All levers shall be level and connections plumb throughout the scale.

SECTION XXIV—SCALE WEIGH-BRIDGES

1. **Type of Girders.**—The girders shall be built of plates and angles and shall preferably be of the fish-belly type so as to reduce the depth of the pit to reasonable limits.

2. **Steel Specifications.**—Material and workmanship shall conform to the Specifications for Steel Railway Bridges of the American Railway Engineering Association, punched and reamed work.

3. **Size and Strength.**—For 200-ton per section scales, the scale weigh-bridge shall be designed for Cooper's E-70 loading, to which shall be added a dead load of 1500 lb. per linear foot of track. For 150-ton per section scales, the scale weigh-bridge shall be designed for Cooper's E-60 loading, to which shall be added a dead load of 1100 lb. per linear foot of track. To the maximum live load stresses computed from the foregoing shall be added 60 per cent of the impact, or dynamic increment of such live load, as determined by the following formula:

$$I = S \times \frac{300}{300 + \frac{L^2}{100}}$$

$$I_s = 60 \text{ per cent of } I, = \frac{18{,}000 \times S}{30{,}000 + L^2}$$

where I = the impact or dynamic increment specified by the A.R.E.A. Specifications for Steel Railway Bridges to be added to the live load stresses.

I_s = 60 per cent of I

S = the computed maximum live load stress

L = the length in feet of the span

Under these loading conditions, the maximum resultant unit stresses shall not exceed the following:

	Lb. per sq. in.
Axial tension, net section	16,000
Axial compression, gross section	$15{,}000 - 50\frac{l}{r}$
but not to exceed	12,500
l = the length of the member in inches	
r = the least radius of gyration of the member	
Tension in extreme fibers of rolled shapes, built sections and girders, net section	16,000
Compression in extreme fibers of rolled shapes, built sections and girders, gross section	$16{,}000 - 150\frac{l}{b}$
l = length in inches of the unsupported flange between lateral connections or knee braces	
b = flange width in inches	
NOTE.—Gross area of compression flanges to be not less than gross area of tension flanges.	
Tension in extreme fibers of pins	24,000
Shear in plate girder webs, gross section	10,000
Horizontal shear in flange angles of girders	4,000
Shear in power driven rivets and pins	12,000
Bearing on power driven rivets, pins, outstanding legs of angle stiffeners, and other steel parts in contact	24,000
Diagonal tension in webs of girders and rolled beams at sections where maximum shear and bending occur simultaneously	16,000

The above mentioned values for shear and bearing shall be reduced 25 per cent for countersunk rivets, hand driven rivets, and turned bolts.

4. **Bracing.**—Each weigh-bridge shall be designed to resist a lateral force of 400 lb. per linear foot, plus four per cent of the sectional capacity of the scale, uniformly distributed along the top of the scale rail.

(a) Diagonal Bracing.—Diagonal bracing shall consist of not less than 3″ by 3″ by 3/8″ angles.

(b) Transverse Bracing.—The ends of the weigh-bridge shall be provided with transverse bracing, of which the section modulus shall not be less than that determined by the formula:

$$S = \tfrac{1}{4} \times (0.04C + 400L) \times d/10{,}000$$

where $S =$ the section modulus
$C =$ the sectional capacity in pounds
$L =$ the length of the live rail in feet
$d =$ the distance in inches from the knife edge of the main lever to the top of the scale rail.

Intermediate transverse bracing, of a section modulus not less than that determined by the above formula, shall also be provided, spaced not farther apart than the distance between alternate stiffeners.

(c) Stiffeners.—Not less than two pairs of stiffener angles shall be provided over each bearing of the girders and, in addition, suitable angle stiffeners shall be used throughout the length of the girders, spaced not farther apart than the unsupported depth of the web plates. The ends of these stiffeners shall be milled to fit the girder flanges where bearing stress is transmitted from the stiffener to the flange.

5. **Fabrication and Assembly.**—In order to avoid distortion, weigh-bridges shall be assembled and riveted up complete with all bracing, except lower flange transverse and diagonal bracing, in the shop under proper inspection.

6. **Scale Rail Pedestals.**—The scale rails shall be carried on metal pedestals spaced not over 30 inches, center to center, which shall be mounted on metal ties or directly on the weigh-bridge. The tops of the pedestals shall be machined. The bottoms of the pedestals shall be machined unless type metal or equivalent is to be poured between such bottoms and the surfaces supporting them.

7. **Rails.**—The weight of the scale rails shall not be less than 100 lb. per yard. Full length rails without splices should be used. In all cases new rails shall be used and, where splices are necessary, they shall be applied accurately.

8. **Clearance Along Scale Rails.**—The clearance between the scale rails, or their pedestals, and the rigid deck shall be not less than 1½ inches. The openings shall be protected from the weather and dirt.

SECTION XXV—APPROACH RAILS

Positive means shall be provided to prevent creeping of the ends of approach rails and to maintain a clearance, which shall be not less than ¼ inch nor more than ¾ inch, between the approach rails and the scale rails unless some special means are employed to reduce impact when wheel loads pass from approach rails to scale rails. The effects of rail creeping may be eliminated by the use of certain proprietary devices now on the market, or by the use of switch points and bent stock rails placed in the approach track in the same alinement and plane with the scale rails. In all cases the fixed section of rail or switch point next adjacent to the scale rail is to be securely fastened to the approach wall by means of bolts anchored therein.

SECTION XXVI—DECK

1. **Type.**—The deck or platform shall be of the fixed type, except to meet special cases.

2. **Construction.**—The material for the deck shall be either reinforced concrete, wooden planking, or metal plates covered to prevent slipping, and as impervious to water as practicable.

3. **Clearances.**—The clearance between the bottom of the fixed deck beams or deck supports and the top of the weigh-bridge shall be not less than two inches.

4. **Strength.**—When wooden planking is used for the deck, it shall be supported by steel floor beams, spaced not over 30 inches, center to center, each of which shall have a section modulus of not less than 14.

SECTION XXVII—TRANSVERSE BEAMS SUPPORTING APPROACH RAILS

The transverse beams at each end of the scale shall each have a section modulus of not less than 250 for 200-ton per section scales, or 197 for 150-ton per section scales. The transverse beams shall be securely fastened to the end walls of the pit.

SECTION XXVIII—WEATHER AND DIRT SHIELDS

1. **Weather Guards.**—Substantial metal guards shall be provided to cover the openings between the scale rails and the deck, to exclude dirt, snow and rain. They shall be so designed and fastened in place that they will be secure, but may be easily removed for inspection or repairs, and will not interfere with the accuracy of the scale when deflection of the weigh-bridge under capacity load occurs.

2. **Dirt Shields.**—Substantial metal shields shall be provided throughout the pit, over all scale bearings and connections, applied to the deck, structural steel or scale parts, to prevent water or dirt falling into them or the accumulation of dirt or ice at points where it would interfere with the action of the scale parts.

SECTION XXIX—LIGHT, DRAINAGE AND VENTILATION

1. **Light.**—Proper lighting of the scale weigh-beam, scale house, scale deck and scale pit shall be provided.

2. **Drainage.**—The scale pit should be kept free from water by adequate drainage.

3. **Ventilation:**

(a) Requirement.—All scale pits shall be ventilated to meet the needs of each particular case, the object being to have the least possible amount of moisture in the pit to prevent rusting of scale parts and structural steel.

(b) Automatic Natural Ventilation.—The following arrangement is recommended for securing natural ventilation: An opening should be made to the pit at each corner to connect with flues which terminate near the bottom of the pit, and another opening without flues extending downward should be made into the pit at its top and near its center. With such an arrangement circulation will always tend to be set up by the air whenever the pit is warmer or more moist than the outside. When the pit is cooler or drier than the outside, circulation will tend automatically to stop. When this is done, circulation will be set up only when it will tend to dry the pit.

SECTION XXX—ENTRANCE TO SCALE PIT

1. **Location.**—Entrance to scale pit for the purpose of inspection shall be through either the floor of the scale house or the foundation wall, and shall be closed by a suitable door so fastened as to prevent entrance of unauthorized persons.

2. **Hatches in Deck.**—If it is desired to have hatches or openings in the deck, except such as are provided for ventilation, they shall be securely fastened from the inside of the pit.

SECTION XXXI—PROTECTION FROM CORROSION

1. **Shop Painting.**—All scale parts and structural steel shall be painted with one coat of red lead paint before leaving the factory. In riveted work, the surfaces coming in contact shall be given one coat of red lead paint before being riveted together. All parts inaccessible after erection shall be given a second shop coat of red lead paint.

2. **Field Painting.**—Scales and structural steel work shall be cleaned and painted with one coat, preferably two coats, of paint in the field before installation.

[14]NON-RETROACTIVE TOLERANCES FOR HEAVY-DUTY AUTOMATIC INDICATING SCALES

DEFINITION.—A heavy-duty automatic indicating scale is a scale, other than the counter-scale type, in which is embodied or to which is attached a self-acting mechanism, the capacity of which may be equal to or less than the total capacity of the scale, through the agency of which the indicated or recorded weights of variable loads may be obtained. This classification does not include scales which automatically weigh out commodities in predetermined drafts, such as automatic grain hopper scales, packaging scales, etc.

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[14] Adopted, Vol. 26, 1925, pp. 658, 1388.

Note.—The tolerances herein presented for consideration are, as is stated above, not intended to be applied strictly to scales already in use. These tolerances are not to be construed as applying to railroad track scales, whether or not automatic indicating devices are embodied in or attached to such scales.

Tolerances

The tolerances to be allowed in excess or deficiency on heavy-duty automatic indicating scales shall be the values shown in the following table:

Load in Pounds	—Tolerance, Class A—		—Tolerance, Class B—	
	On Ratio Ounces	On Dial or Beam Ounces	On Ratio Ounces	On Dial or Beam Pounds
50	½	1	..	..
100	1	2	..	..
200	2	4	..	..
300	3	6	..	..
400	4	8	..	..
500	5	10	10	1¼
600	6	12	12	1½
		Pounds	Pounds	
800	8	1	1	2
1,000	8	1	1	2
1,200	10	1¼	1¼	2½
1,500	12	1½	1½	3
1,800	14	1¾	1¾	3½
	Pounds			
2,000	1	2	2	4
2,500	1¼	2½	2½	5
4,000	2	4	4	8
6,000	3	6	6	12
8,000	4	8	8	16
10,000	5	10	10	20
12,000	6	12	12	24
16,000	8	16	16	32
20,000	10	20	20	40
24,000	12	24	24	48
30,000	15	30	30	60
40,000	20	40	40	80
50,000	25	50	50	100

Provided, however, that the tolerances on the dial or reading face on all these automatic indicating scales shall in no case be less than the value of one of the minimum graduations on the dial or reading face, or one five-hundredth of the capacity of the dial or reading face, whichever is less, except that on such of these scales as have a minimum graduation of 1 pound or more on the dial or reading face such tolerance shall not be less than 1 pound. The tolerances on any beam or beams with which the scale may be equipped shall be the same as those specified above, except in cases where the value of the minimum graduation on any such beam is less than that of the minimum graduation on the dial or reading face, or one five-hundredth of the capacity thereof, whichever determines the minimum tolerance on the dial or reading face, in which cases the minimum tolerance on any such beam shall be the minimum graduation on any beam with which the scale may be equipped.

The minimum tolerance to be allowed on the ratio or the multiplying power of the scale shall be the same as the minimum tolerance allowed on the beam: And provided further, that the manufacturers' tolerances or the tolerances on all new heavy-duty automatic indicating scales shall be one-half of the values specified above.

The tolerances to be allowed on heavy-duty automatic indicating scales used exclusively in determining weights for the sole purpose of fixing charges for the transportation of freight shall be twice those specified above.

Note.—The values given in the above table are the same as those adopted by the Eleventh Annual Conference for platform scales of the beam type and incorporated in Bureau of Standards Circular No. 61 and Handbook No. 1.

Explanation of Preceding Table—Class A scales include the following: Scales of the portable platform type; and also scales of the self-contained or dormant and built-in types which are installed inside of a building having side walls and roof, which protect the scale from weather effects and from sudden changes of temperature.

Class B scales include the following: Scales of the motor truck and wagon types; and also scales of the self-contained or dormant and built-in types which are not installed inside of a building having side walls and roof and which are exposed to weather effects and sudden changes of temperature.

Note.—The latter effect, since it causes the condensation of moisture on the scale parts, often has as serious results on the condition of the scales as have weather effects.

The values in the columns with the headings "Tolerance," "On ratio" are to be applied to the ratio or multiplying power of such scales with which loose counterpoise or "bottle" weights are used; namely, those which are manually applied and removed and are not an integral part of the scale mechanism.

The values in the columns with the headings "Tolerance," "On dial or beam" are to be applied to those parts of such scales not requiring the use of loose weights; for example, the dial, a beam, or "built-in" automatic or semiautomatic counterpoise or unit weights; namely, those which are automatically or mechanically added and are an integral part of the scale mechanism and not designed to be detached therefrom.

Tolerance on Weights

The tolerances to be allowed on loose counterpoise or "bottle" weights used on heavy-duty automatic indicating scales shall be the same as those specified for such weights used on beam scales.

[15]DISPOSITION OF OBSOLETE TRACK SCALES

A track scale which has been removed by reason of inadequacy, obsolescence or inaccuracy, should be disposed of in either of the following ways:

(1) Treat as scrap metal after rendering unfit for further use as a scale or parts thereof.

(2) Retain for use as repair parts of existing scales of the same type and size.

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[15] Adopted, Vol. 29, 1928, pp. 438, 1341.

COMMITTEE XV

IRON AND STEEL STRUCTURES

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[1]SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

For Fixed Spans Less Than 300 Feet in Length

FOREWORD

The purpose of the Committee in writing these specifications was to formulate specific and detailed rules for the design and manufacture of bridges, as a guide to both the designer and the shop, rather than to confine the specifications to a statement of principles or to limit them to rules defining the duties of the contractor. The intention was to describe the best general practice for standard American and Canadian railroads, and to advance the causes of good design and workmanship. The requirements of light and branch railroads and foreign practice have not been considered.

The Clearance Diagram in these specifications is intended to apply to new construction work only. It provides for the future development of motive power to a width of eleven feet.

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[1] Adopted, Vol. 4, 1903, pp. 130, 141, 142, 253; Vol. 5, 1904, p. 581; Vol. 6, 1905, pp. 228, 239, 448, 481; Vol. 7, 1906, pp. 185, 236; Vol. 11, 1910, part I, pp. 115, 160; Vol. 21, 1920, pp. 491, 1414; Vol. 25, 1924, pp. 1072, 1262.

QUESTIONS TO BE ANSWERED FOR THE INFORMATION OF BIDDERS

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2.	Is the alinement straight or curved? If on a curve, what is the superelevation of the outer rail and what is the degree of the curve?	13
3.	What is the rate and the direction of grade on the bridge?	92
4.	What are the conditions at the site? Furnish plans showing the general dimensions and conditions governing the design of the structure: Length of spans Types of spans Number and spacing of tracks Angle of skew Type of floor Limiting under-clearance	2
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(I) PROPOSALS AND DRAWINGS

Definitions of Terms

1. The term "Engineer" refers to the Chief Engineer of the Company or his subordinates in authority. The term "Inspector" refers to the inspector representing the Company. The term "Company" refers to the Railway Company party to the contract. The term "Contractor" refers to the manufacturing or fabricating contractor party to the contract.

Proposals

2. Bidders shall submit proposals to conform with the terms in the letter of invitation. The proposals preferably shall be based on plans and specifications furnished by the Company showing the general dimensions necessary for designing the structure, the stresses and the general or typical details. Invitations covering work to be designed or erected by the Contractor shall state the general conditions at the site, such as track spacing, character of foundations, old structures, traffic conditions, etc.

Drawings to Govern

3. Where the drawings and the specifications differ, the drawings shall govern.

Patented Devices

4. The Contractor shall protect the Company against claims on account of patented devices or parts proposed by him.

Drawings

5. After the contract has been awarded and before any work is commenced, the Contractor shall submit to the Engineer for approval duplicate prints of stress sheets and shop drawings, unless such drawings shall have been prepared by the Company. The tracing of these drawings shall be the property of and be delivered to the Company after the completion of the contract. Shop drawings shall be made on the dull side of the tracing cloth, 24 by 36 inches in size, including margins. The margin at the left end shall be 1½ inches wide, and the others ½ inch. The title shall be in the lower right-hand corner. No changes shall be made on any approved drawing without the consent, in writing, of the Engineer.

6. The Contractor shall be responsible for the correctness of his drawings, and for shop fits and field connections, although the drawings may have been approved by the Engineer.

7. Any material ordered by the Contractor prior to the approval of the drawings shall be at his risk.

(II) GENERAL FEATURES OF DESIGN

Materials Used

8. Structures shall be made wholly of structural steel except where otherwise specified. Rivet steel shall be used for rivets only. Cast steel preferably shall be used for shoes and bearings. Cast iron may be used only where specifically authorized by the Engineer.

Types of Bridges

9. The different types of bridges may be used as follows:

Rolled beams for spans up to 35 feet.
Plate girders for spans from 30 feet to 125 feet.
Riveted trusses for spans from 100 feet to 300 feet.
Pin-connected trusses for spans from 150 feet to 300 feet.

Number of Trusses

10. Unless otherwise specified, double-track through bridges shall have only two trusses or girders, and four-track bridges three.

Dimensions for Calculation

11. The dimensions for the calculation of stresses shall be as follows:

Span Length

For trusses and girders, the distance center to center of end bearings.
For floor-beams, the distance center to center of trusses or girders.
For stringers, the distance center to center of floor-beams.

Depth

For riveted trusses, the distance between centers of gravity of chord sections.

For pin-connected trusses, the distance center to center of chord pins.

For plate girders, floor-beams, and stringers, the distance between centers of gravity of flanges, but not to exceed the distance back to back of the flange angles.

Spacing Trusses, Girders, and Floor-beams

12. The width center to center of girders or trusses shall be not less than one-fifteenth of the effective span, and not less than is necessary to prevent overturning under the assumed lateral loading. Panel lengths shall not exceed 1½ times the width, c. to c. of trusses or girders.

Clearances

13. If the alinement is straight, clearances shall be not less than as shown on the diagram, Fig. 1. If the alinement is curved, the width of the diagram shall be so increased as to provide the same minimum clearances for a car 80 feet long, 14 feet high and 60 feet center to center of trucks, allowance being made for curvature and superelevation of rails. The height of rail shall be assumed as 6 inches.

Deck Spans on Curves

14. Deck spans on curves usually shall be so placed that the center line of the span will bisect the middle ordinate of, and be parallel to the chord of the curve.

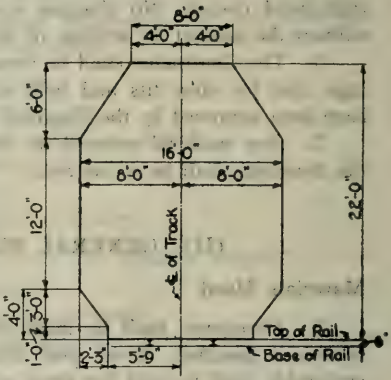

FIG. 1

Skew Bridges

15. In skew bridges without ballasted floors, the ends of stringers or girders for each track shall be square with the track.

Ambiguity of Stress

16. Structures shall be so designed as to avoid, as far as practicable, ambiguity in the determination of the stresses.

(III) LOADS

Loads

17. The structures shall be proportioned for the following loads:

- a. Dead load.
- b. Live load.
- c. Impact or dynamic effect of the live load.
- d. Lateral loads and forces.
- e. Centrifugal force, including impact.
- f. Longitudinal force.

Stresses due to these loads and forces shall be shown separately on the stress sheets.

18. Members shall be proportioned for that combination of stresses which gives the maximum total stress, except as otherwise provided.

Dead Load

19. The dead load shall consist of the estimated weight of the entire suspended structure. Timber shall be assumed to weigh 4½ pounds per foot B. M.; ballast, assumed level with the base of rail and including track ties embedded therein, 120 pounds per cubic foot; reinforced concrete, 150 pounds per cubic foot; waterproofing, 150 pounds per cubic foot; and rails and fastenings, 150 pounds per linear foot of track.

Live Load

20. The minimum live load for each track shall be as shown in Fig. 2 and 3, except as modified in Section 21.

The loading that gives the larger stresses shall be used.

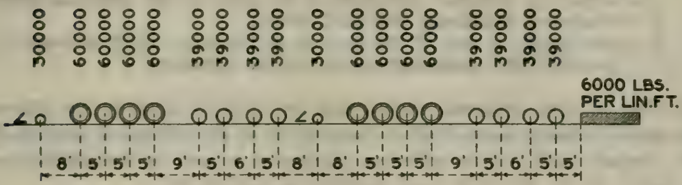

Fig. 2

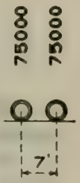

Fig. 3

21. In special locations, where conditions limit the loading to light engines, a lighter loading, as stipulated by the Engineer, may be used, but in no case less than three-fourths of that specified in Section 20. The live load assumed shall be proportional to the loading specified in Section 20, with the same wheel spacing.

22. A train load of 1200 pounds per linear foot of one track shall be used in determining the stability of spans and towers against overturning.

Multiple Tracks

23. In calculating the maximum stresses due to live load and centrifugal force when two, three or four tracks are loaded simultaneously, the following percentages of the specified live load shall be used:

For two tracks, 90 per cent.
For three tracks, 80 per cent.
For four tracks, 75 per cent.

Floors

24. Timber cross-ties shall be designed for the maximum wheel load distributed over three ties and with 100 per cent impact added. The fiber stress shall not exceed 2000 pounds per square inch. The ties shall be not less than 10 feet in length. They shall be spaced with openings not exceeding 4 inches and shall be secured against bunching. The maximum dap of ties shall be 1¼ inches.

25. Floors consisting of beams transverse to the axis of the structure shall be designed for a uniform live load of 15,000 pounds per linear foot for each track, with 100 per cent impact added, when the minimum

live load specified in Section 20 is used. When heavier loadings are used, this uniform load shall be increased proportionately.

26. Floors consisting of longitudinal beams shall be designed for the wheel loads specified.

27. In ballasted floor bridges, the live load shall be considered as uniformly distributed laterally over a width of 10 feet.

Impact

28. The dynamic increment of the live load shall be added to the maximum computed live load stresses and shall be determined by the formula

$$I = S \frac{300}{300 + \frac{L^2}{100}}, \text{ in which}$$

I = impact or dynamic increment to be added to the live-load stress.
S = computed maximum live-load stress.
L = the length in feet of the portion of the span which is loaded to produce the maximum stress in the member.

29. For bridges designed exclusively for electric traction, the impact stresses shall be taken as one-half of those given by the formula in Section 28.

30. Impact shall not be added to stresses produced by longitudinal or lateral forces, or by the train load specified in Section 22.

Eccentricity of Load on Curves

31. For bridges on curves, provision shall be made for the increased load carried by any truss, girder or stringer due to the eccentricity of the load.

Lateral Forces

32. The wind force on the structure shall be a moving load of 30 pounds per square foot on 1½ times its vertical projection on a plane parallel with its axis, but not less than 200 pounds per linear foot at the loaded chord or flange, and 150 pounds per linear foot at the unloaded chord or flange.

The wind force on the train shall be a moving load of 300 pounds per linear foot on one track, applied 8 feet above the base of rail.

33. The lateral force to provide for the effect of the sway of the engines and train in addition to the wind loads specified in Section 32, shall be a moving load equal to 5 per cent of the specified live load on one track, but not more than 400 pounds per linear foot, applied at the base of rail.

34. The lateral bracing between compression chords or flanges and between the posts of viaduct towers shall be capable of resisting a transverse shear in any panel equal to 2½ per cent of the total axial stress in the chords or posts in that panel.

35. In proportioning the bracing, Sections 32 and 33 shall be combined or Section 34 used alone, whichever gives the greater section.

Centrifugal Force

36. On curves, the centrifugal force (assumed to act 6 feet above the rail) shall be taken equal to a percentage of the live load, including impact, according to the following table:

Degree of Curve	0° 20′	0° 40′	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°
Percentage	2½	5	7½	10	10	10	10	10	10	10	10	10	10	10
Speed in miles per hour	80	80	80	65	53	46	41	38	35	33	31	29	28	27

Longitudinal Force

37. Provision shall be made in the design for the effect of a longitudinal force of 20 per cent of the live load on one track only, applied 6 feet above the top of the rail. In structures (such as ballasted deck bridges of only three or four spans) where, by reason of continuity of members or frictional resistance, the longitudinal force will be largely directed to the abutments, its effect on the superstructure shall be taken as one-half that specified above.

(IV) UNIT STRESSES AND PROPORTIONING OF PARTS

38. The several parts of structures shall be so proportioned that the unit stresses will not exceed the following, except as modified in Sections 46 and 47:

	Pounds per sq. inch
Axial tension, net section	16,000
Axial compression, gross section	$15{,}000 - 50\frac{l}{r}$
but not to exceed	12,500
l = the length of the member in inches.	
r = the least radius of gyration of the member in inches.	
Tension in extreme fibers of rolled shapes, built sections and girders, net section	16,000
Tension in extreme fibers of pins	24,000
Shear in plate girder webs, gross section	10,000
Shear in power-driven rivets and pins	12,000
Bearing on power-driven rivets, pins, outstanding legs of stiffener angles, and other steel parts in contact	24,000
Rivets driven and bucked by pneumatically or electrically operated hammers are considered power driven.	
The above mentioned values for shear and bearing shall be reduced 25 per cent for countersunk rivets, hand driven rivets and turned bolts.	
Bearing on expansion rollers, per linear inch	$600d$
d = the diameter of the rollers in inches.	

	Pounds per sq. inch
Bearing on granite masonry	800
Bearing on sandstone and limestone masonry	400
Bearing on concrete masonry	600

39. For cast steel in shoes and bearings, the above mentioned unit stresses shall apply.

40. The diagonal tension in webs of girders and rolled beams at sections where maximum shear and bending occur simultaneously, shall not exceed 16,000 pounds per square inch.

Effective Bearing Area

41. The effective bearing area of a pin, a bolt or a rivet shall be its diameter multiplied by the thickness of the piece, except that for countersunk rivets, half the depth of the countersink shall be omitted.

Effective Diameter of Rivets

42. In proportioning rivets, the nominal diameter of the rivet shall be used.

Proportioning Web Members

43. Web members shall be so proportioned that an increase of live load which will increase the total unit stresses in the chords 50 per cent will not produce total unit stresses in the web members more than 50 per cent greater than the designing stresses.

Reversal of Stress

44. Members subject to reversal of stress under the passage of the live load shall be proportioned as follows:

Determine the resultant tensile stress and the resultant compressive stress and increase each by 50 per cent of the smaller; then proportion the member so that it will be capable of resisting either increased resultant stress. The connections shall be proportioned for the sum of the resultant stresses.

Combined Stresses

45. Members subject to both axial and bending stresses (including bending due to floor-beam deflection) shall be so proportioned that the combined fiber stresses will not exceed the allowed axial stress. In members continuous over panel points, only three-fourths of the bending stress computed as for simple beams shall be added to the axial stress.

46. Members subject to stresses produced by a combination of dead load, live load, impact, and centrifugal force, with either lateral or longitudinal forces, or bending due to lateral action, may be proportioned for unit stresses 25 per cent greater than those specified in Section 38; but the section shall not be less than that required for dead load, live load, impact, and centrifugal force.

Secondary Stresses

47. Designing and detailing shall be done so as to avoid secondary stresses as far as possible. In ordinary trusses without sub-paneling, no account usually need be taken of the secondary stresses in any member whose width measured in the plane of the truss is less than one-tenth of its length. Where this ratio is exceeded, or where sub-paneling is used, secondary stresses due to deflection of the truss shall be computed. The unit stresses specified in Section 38 may be increased one-third for a combination of the secondary stresses with the other stresses, but the section shall not be less than that required when secondary stresses are not considered.

Compression Flanges

48. The gross area of the compression flanges of plate girders and rolled beams shall not be less than the gross area of the tension flanges, but the stress per square inch of gross area shall not exceed

$$16{,}000 - 150\frac{l}{b}, \text{ in which}$$

l = the length in inches of the unsupported flange between lateral connections or knee braces.
b = the flange width in inches.

(V) DETAILS OF DESIGN

Slenderness Ratios

49. The ratio of length to least radius of gyration shall not exceed:

100 for main compression members.
120 for wind and sway bracing.
140 for single lacing, and for double lacing not riveted at intersections.
170 for double lacing riveted at intersections.
200 for riveted tension members.

Depth Ratios

50. The depth of trusses preferably shall be not less than one-tenth of the span. The depth of plate girders preferably shall be not less than one-twelfth of the span. The depth of rolled beams used as girders and the depth of solid floors preferably shall be not less than one-fifteenth of the span. If smaller depths than these are used, the section shall be so increased that the maximum deflection will not be greater than if these limiting ratios had not been exceeded.

Parts Accessible

51. Details shall be so designed that all parts will be accessible for inspection, cleaning and painting. Closed sections shall be avoided wherever possible.

Pockets

52. Pockets or depressions which would hold water shall have efficient drain holes, or shall be filled with concrete.

Eccentric Connections

53. Members shall be so connected that their gravity axes will intersect in a point. Eccentric connections shall be avoided if practicable, but, if unavoidable, the members shall be so proportioned that the combined fiber stresses will not exceed the allowed axial stress.

Effective Area of Angles

54. The effective area of single angles in tension shall be assumed as the net area of the connected leg plus 50 per cent of the area of the unconnected leg. Single angles connected by lug angles shall be considered as connected by one leg.

Counters

55. If web members are subject to reversal of stress, their end connections preferably shall be riveted. Adjustable counters shall have open turnbuckles.

Strength of Connections

56. Connections shall have a strength at least equal to that of the members connected, regardless of the computed stress. Connections shall be made, as nearly as practicable, symmetrical about the axes of the members.

Limiting Thickness of Metal

57. Metal shall be not less than ⅜ inch thick, except for fillers. Metal subject to marked corrosive influences shall be increased in thickness or protected against such influences.

Sizes of Rivets

58. Rivets shall be ¾ inch, ⅞ inch or 1 inch in diameter as specified.

Pitch of Rivets

59. The minimum distance between centers of rivet holes shall be three diameters of the rivet, but the distance preferably shall be not less than 3½ inches for 1-inch rivets, 3 inches for ⅞-inch rivets and 2½ inches for ¾-inch rivets. The maximum pitch in the line of stress for members composed of plates and shapes shall be 7 inches for 1-inch rivets, 6 inches for ⅞-inch rivets and 5 inches for ¾-inch rivets. For angles with two gage lines and rivets staggered, the maximum pitch in each line shall be twice the amounts given above. If two or more web plates are used in contact, stitch rivets shall be provided to make them act in unison. In compression members, the stitch rivets shall be spaced not more than 24 times the thickness of the thinnest plate in the direction perpendicular to the line of stress, and not more than 12 times the thickness of the thinnest plate in the line of stress. In tension members, the stitch rivets shall be spaced not more than 24 times the thickness of the thinnest outer plate in either direction. In tension members composed of two angles in contact, a pitch of 12 inches may be used for riveting the angles together.

Edge Distance

60. The minimum distance from the center of any rivet hole to a sheared edge shall be: 1¾ inches for 1-inch rivets, 1½ inches for ⅞-inch rivets and 1¼ inches for ¾-inch rivets; to a rolled edge 1½ inches, 1¼ inches and 1⅛ inches, respectively. The maximum distance from any edge shall be eight times the thickness of the plate, but shall not exceed 6 inches.

Sizes of Rivets in Angles

61. The diameter of the rivets in any angle whose size is determined by calculated stress shall not exceed one-fourth of the width of the leg in which they are driven. In angles whose size is not so determined 1-inch rivets may be used in 3½-inch legs, ⅞-inch rivets in 3-inch legs, and ¾-inch rivets in 2½-inch legs.

Long Rivets

62. Rivets which carry calculated stress and whose grip exceeds four and one-half diameters shall be increased in number at least one per cent for each additional 1/16 inch of grip. If the grip exceeds six times the diameter of the rivet, specially designed rivets shall be used.

Pitch of Rivets at Ends

63. The pitch of rivets at the ends of built compression members shall not exceed four diameters of the rivet for a distance equal to one and one-half times the maximum width of the member.

Compression Members

64. In built compression members, the metal shall be concentrated in the webs and flanges. The thickness of each web shall be not less than one-thirtieth of the distance between the lines of rivets connecting it to the flanges. The thickness of cover plates shall be not less than one-fortieth of the distance between the nearest rivet lines.

Outstanding Legs of Angles

65. The width of the outstanding legs of angles in compression (except when reinforced by plates) shall not exceed the following:

(a) For stringer flange angles, ten times the thickness.
(b) For main members carrying axial stress, twelve times the thickness.
(c) For bracing and other secondary members, fourteen times the thickness.

Stay Plates

66. The open sides of compression members shall be provided with lacing bars and shall have stay plates as near each end as practicable. Stay plates shall be provided at intermediate points where the lacing is interrupted. In main members, the length of the end stay plates shall be not less than 1¼ times the distance between the lines of rivets connecting them to the outer flanges, and the length of intermediate stay plates shall be not less than three-quarters of that distance. Their thickness shall be not less than one-fiftieth of the same distance.

67. Tension members composed of shapes shall have their separate segments stayed together. The stay plates shall have a length not less than two-thirds of the lengths specified for stay plates on compression members.

Lacing

68. The lacing of compression members shall be proportioned to resist a shearing stress of 2½ per cent of the direct stress. The section shall be made as required by Sections 38 and 49, in which l shall be taken as the distance between connections of the lacing to the main sections.

The minimum width of lacing bars shall be 3 inches for 1-inch rivets, 2¾ inches for ⅞-inch rivets, 2½ inches for ¾-inch rivets, and 2 inches for ⅝-inch rivets.

69. In members composed of side segments and a cover plate, with the open side laced, one-half the shear shall be considered as taken by the lacing. Where double lacing is used, the shear in the plane of the lacing shall be distributed equally between the two systems.

70. Lacing bars of compression members shall be so spaced that the *l/r* of the portion of the flange included between their connections will be not greater than 40, and not greater than two-thirds of the *l/r* of the members.

71. In connecting lacing bars to flanges, ⅝-inch rivets shall be used for flanges less than 2½ inches wide, ¾-inch rivets for flanges from 2½ to 3½ inches wide, and ⅞-inch rivets for flanges 3½ or more inches wide. Lacing bars with at least two rivets in each end shall be used for flanges over 5 inches wide.

72. The angle of lacing bars with the axis of the member shall be not less than 45 degrees for double lacing, and 60 degrees for single lacing. If the distance between rivet lines in the flanges is more than 15 inches and a single-rivet bar is used, the lacing shall be double and riveted at the intersections.

Splices

73. Abutting joints in compression members faced for bearing shall have their component parts spliced. The gross area of the splice material shall be not less than 50 per cent of the gross area of the smaller member. In determining the number of rivets in compression splices, the stress in the splice material shall be taken as 15,000 pounds per square inch of gross area.

74. Joints in riveted work not faced for bearing shall be fully spliced.

Net Section at Pin Holes

75. In pin-connected riveted tension members, the net section across the pin hole shall be not less than 140 per cent and the net section back of the pin hole not less than 100 per cent of the net section of the body of the member, and there shall be sufficient rivets to make the material effective.

Net Section Defined

76. The net section of riveted members shall be the least area which can be obtained by deducting from the gross sectional area the areas of holes cut by any plane perpendicular to the axis of the member and parts of the areas of other holes on one side of the plane within a distance of four inches, which are on gage lines one inch or more from those of the holes cut by the plane, the parts being determined by the formula:

$$A\left[1-\frac{P}{4}\right] \text{in which}$$

A = the area of the hole.
P = the distance in inches of the center of the hole from the plane.

77. In determining the net section, the diameter of the rivet hole shall be taken one-eighth inch larger than the nominal diameter of the rivet.

Pin Plates

78. Where necessary to give the required section or bearing area, pin holes shall be reinforced on each segment by plates, one of which on each side must be as wide as the outstanding flanges will permit. These plates shall contain enough rivets and be so connected as to transmit and distribute

the bearing pressure uniformly over the full cross-section and to reduce the eccentricity of the segment to a minimum. At least one full-width plate on each segment shall extend to the far edge of the stay plate and the others not less than 6 inches beyond the near edge.

Indirect Splices

79. If splice plates are not in direct contact with the parts which they connect, rivets shall be used on each side of the joint in excess of the number required in the case of direct contact to the extent of two extra lines for each intervening plate.

Fillers

80. Where rivets carrying stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by additional rivets sufficient to develop the value of the filler.

Forked Ends

81. Forked ends on compression members will be permitted only where unavoidable. Where forked ends are used, a sufficient number of pin plates shall be provided to make the jaws of twice the sectional area of the member and they shall be extended as far as necessary in order to carry the stress of the main member into the jaws, but shall not be shorter than required by Section 78.

Pins

82. Pins shall be long enough to secure a full bearing of all parts connected upon the turned body of the pin. They shall be secured by chambered nuts or by solid nuts with washers. Where the pins are bored, through rods with cap washers may be used. The screw ends shall be long enough to allow burring the threads.

83. Pin-connected members shall be held against lateral movement on the pins.

Bolts

84. Where members are connected by bolts, the turned bodies of the bolts shall be long enough to extend through the metal. A washer at least ¼ inch thick shall be used under the nut. Bolts shall not be used except by special permission.

Upset Ends

85. Bars with screw ends shall be upset so that the area at the root of the thread will be at least 15 per cent greater than in the body of the bar.

Sleeve Nuts

86. Sleeve nuts shall not be used.

Expansion

87. Provision shall be made for expansion and contraction at the rate of one inch for every 100 feet in length. The expansion ends shall be secured against lateral movement. In spans more than 250 feet in length, provision shall be made for expansion in the floor.

Expansion Bearings

88. Spans more than 70 feet in length shall have rollers at one end. Shorter spans will be arranged to slide on smooth surfaces.

Fixed Bearings

89. Bearings and ends of spans shall be secured against lateral motion.

Rollers

90. Expansion rollers shall be not less than 6 inches in diameter. They shall be coupled together with substantial side bars, which shall be so arranged that the rollers can be cleaned readily. Rollers shall be geared to the upper and lower plates.

Pedestals and Shoes

91. Pedestals and shoes preferably shall be made of cast steel. The difference between the top and bottom bearing widths shall not exceed twice the depth. For hinged bearings, the depth shall be measured from the center of the pin. Where built pedestals and shoes are used, the web plates and the angles connecting them to the base plate shall be not less than ¾ inch thick. If the size of the pedestal permits, the webs shall be rigidly connected transversely. The minimum thickness of the metal in cast steel pedestals shall be one inch. Pedestals and shoes shall be so constructed that the load will be distributed uniformly over the entire bearing. Spans more than 70 feet in length shall have hinged bearings at each end.

Inclined Bearings

92. For spans on an inclined grade and without hinged bearings, the sole or masonry plates shall be beveled so that the masonry surfaces will be level.

Name Plates

93. There shall be a name plate, showing in raised letters and figures the name of the manufacturer and the year of construction, bolted to the bridge near each end at a point convenient for inspection.

(VI) FLOORS

Types of Floors

94. Floors may consist of steel floor-beams and stringers, with timber cross-ties supporting the rails, or of one of the solid floor types.

Ballasted Floors

95. Ballasted floors shall have not less than 6 inches of ballast under the ties.

Floor Members

96. Floor members shall be designed with special reference to stiffness.

97. Specifications for plate girders shall apply to floor-beams and stringers.

Spacing of Stringers

98. Stringers usually shall be spaced 6 feet 6 inches center to center. If four stringers are used under one track, each pair shall be placed symmetrically about the rail.

I-Beam Girders

99. Rolled beams supporting timber decks shall be arranged with not more than four, and preferably not less than two, beams under each rail. The beams in each group shall be placed symmetrically about the rail, and shall be spaced far enough apart to permit cleaning and painting. They shall be connected by solid web diaphragms near the ends and at intermediate points, spaced not over twelve times the flange width. Bearing plates shall be continuous under each group of beams. End stiffeners shall be used if required by Section 38.

Floor-Beam Connections

100. Floor-beams preferably shall be square to the girders or trusses. They shall be riveted directly to the girders or between the posts of through and deck truss spans.

End Connection Angles

101. The legs of stringer connection angles shall be not less than 4 inches in width, and not less than ⅝ inch in thickness before facing. Shelf angles shall be provided to support the stringers during erection, but the connection angles shall be sufficient to carry the whole load. Stringers in through spans shall be riveted between the floor-beams.

Stringer Frames

102. Where two lines of stringers are used under each track in panels more than 20 feet in length, they shall be connected by cross frames.

Solid Floor Connections

103. Solid floors shall be connected to the girders or trusses by angles not less than ⅝ inch thick to be faced, or ½ inch thick if not to be faced—one angle on each side of the web of I-beams and one on each of the vertical members of troughs.

Proportioning Solid Floors

104. Solid floors shall be proportioned by the moments of inertia of the sections, using the net sections including the compression side.

(VII) BRACING

Design of Bracing

105. Lateral, longitudinal and transverse bracing shall be composed of shapes with riveted connections. Lateral bracing shall have concentric connections to chords at end joints, and preferably throughout. The connections between the lateral bracing and the chords shall be designed to avoid, as far as practicable, any bending stress in the truss members.

106. When a double system of bracing is used, both systems may be considered simultaneously effective if the members meet the requirements as both tension and compression members.

Lateral Bracing

107. Bottom lateral bracing shall be provided in all bridges except deck plate girder spans less than 50 feet long. Continuous steel or concrete floors shall be considered lateral bracing.

108. Top lateral bracing shall be provided in deck spans, and in through spans having sufficient head room.

Portal and Sway Bracing

109. Deck truss spans shall have sway bracing at every panel point. The top lateral loads preferably shall be carried to the supports by means of a complete top lateral system, or the loads may be considered as transferred to the bottom lateral system at each sway frame.

110. Through truss spans shall have portal bracing, with knee braces, as deep as the specified clearance will allow.

111. Through truss spans shall have sway bracing at every intermediate panel point if the height of the trusses is enough to allow a depth of 6 feet or more for the bracing. When the height of the trusses will not allow that depth, the top lateral struts shall be of the same depth as the chord and shall have knee braces.

Cross-Frames

112. Deck plate girders spans shall be provided with cross-frames at each end proportioned to resist centrifugal and lateral forces, and shall have intermediate cross-frames at intervals not exceeding 18 feet.

Laterals

113. The smallest angle to be used in lateral bracing shall be 3½ by 3 by ⅜ inches. There shall be not less than three rivets at each end connection of the angles. Angles shall be connected at their intersections by plates.

114. Lateral bracing below the track shall be low enough to clear the ties.

(VIII) PLATE GIRDERS

Spacing of Girders

115. The girders of deck bridges usually shall be spaced 6 feet 6 inches between centers, except that:

(a) In single-track deck spans 75 feet or more in length, the girders shall be spaced in accordance with Section 12, but not less than 7 feet 6 inches between centers.

(b) In bridges on curves, the girders shall be spaced as shown on the plans.

Design of Plate Girders

116. Plate girders shall be proportioned either by the moment of inertia of their net section including compression side; or by assuming that the flanges are concentrated at their centers of gravity. In the latter case, one-eighth of the gross section of the web, if properly spliced, may be used as

flange section. For girders having unusual sections, the moment of inertia method shall be used.

Flange Section

117. The flange angles shall form as large a part of the area of the flange as practicable. Side plates shall not be used except when flange angles exceeding one inch in thickness otherwise would be required.

118. Flange plates shall be equal in thickness, or shall diminish in thickness from the flange angles outward. No plate shall have a thickness greater than that of the flange angles.

119. Where flange cover plates are used, one cover plate of the top flange shall extend the full length of the girder. Other flange plates shall extend at least 18 inches beyond the theoretical end.

Thickness of Web Plates

120. The thickness of web plates shall be not less than $\frac{1}{20}\sqrt{D}$, where D represents the distance between flanges in inches.

Flange Rivets

121. The flanges of plate girders shall be connected to the web with a sufficient number of rivets to transfer to the flange section the horizontal shear at any point combined with any load that is applied directly on the flange. Where ties rest on the flange, one wheel load shall be assumed to be distributed over 3 feet.

Flange Splices

122. Splices in flange members shall not be used except by special permission of the Engineer. No two members shall be spliced at the same cross-section. If practicable, splices shall be located at points where there is an excess of section. The net section of the splice shall exceed by 10 per cent the net section of the member spliced. Flange angle splices shall consist of two angles—one on each side.

Web Splices

123. Web plates shall be spliced symmetrically by plates on each side. The splice plates for shear shall be the full depth of the girders between flanges. The splice shall be equal to the web in strength in both shear and moment. There shall be not less than two rows of rivets on each side of the joint.

End Stiffeners

124. Plate girders shall have stiffener angles over end bearings, the outstanding legs of which will extend as nearly as practicable to the outer edge of the flange angles. These end stiffeners shall be proportioned for bearing of the outstanding legs on the flange angles, and shall be arranged to transmit the end reaction to the pedestals or distribute it over the masonry bearings. They shall be connected to the web by enough rivets to transmit the reaction. End stiffeners shall not be crimped.

Intermediate Stiffeners

125. The webs of plate girders shall be stiffened by angles at intervals not greater than:

(a) Six feet.
(b) The depth of the web.
(c) The distance given by the formula

$$d = \frac{t}{40}(12{,}000 - S)$$

d = the distance between rivet lines of stiffeners in inches.
t = the thickness of the web in inches.
S = web shear in pounds per square inch at the point considered.

126. If the depth of the web between the flange angles or side plates is less than 50 times the thickness of the web, intermediate stiffeners may be omitted.

127. Stiffener angles shall be placed at points of concentrated loads, and shall not be crimped.

128. Intermediate stiffeners shall be riveted in pairs to the web of the girder. The outstanding leg of each angle shall be not less than 2 inches plus one-thirtieth of the depth of the girder, nor more than 16 times its thickness.

Gusset Plates in Through Girders

129. In through plate girder spans, the top flanges shall be braced by means of gusset plates or knee-braces with solid webs connected to the floor-beams and extending usually to the clearance line. If the unsupported length of the inclined edge of the gusset plate exceeds 18 inches, the gusset plate shall have one or two stiffening angles riveted along its edge. The gusset plate shall be riveted to a stiffener angle on the girder. Preferably it shall form no part of the floor-beam web.

130. In through plate girder spans with solid floors, there shall be knee-braces with ⅜-inch webs, extending usually to the clearance line, at intervals of about 12 feet. Each knee-brace shall be well riveted to the floor and the girder, especially at the top, and shall have its edge reinforced by one or two angles.

Ends of Through Girders

131. If plate girders project two feet or more above the base of the rail, the upper corners shall be rounded. In multiple span bridges, usually only the extreme ends shall be rounded. Exposed ends of girders shall be neatly finished with end plates.

Spans Shipped Riveted

132. Deck plate girder spans less than 50 feet in length shall be shipped riveted complete, unless otherwise specified.

Masonry Bearings

133. End bearings on masonry preferably shall be raised above the bridge seat by metal pedestals.

134. Sole plates shall be not less than ¾ inch thick and not less in thickness than the flange plus ⅛ inch. Preferably they shall not be more than 18 inches long.

Anchor Bolts

135. Anchor bolts shall be 1¼ inches in diameter and shall extend 12 inches into the masonry. There shall be washers under the nuts. Anchor bolt holes in pedestals and sole plates shall be 1⅝ inches in diameter, except that at expansion points the holes in the sole plates shall be slotted.

(IX) TRUSSES

Type of Truss and Sections of Members

136. Trusses shall have single intersection web systems and, preferably, inclined end posts. The top chords and end posts shall be made usually of two side segments with one cover plate and with stay plates and lacing on the open side. The bottom chords of riveted trusses shall be made symmetrical, usually of vertical side plates with flange angles. Web members shall be symmetrical in section.

Camber

137. The length of members of truss spans shall be such that the camber will be equal to the deflection produced by the combined dead and live loads without impact.

Riveted Members in Pin-Connected Trusses

138. In pin-connected trusses, hip verticals (and members with similar functions) and, in single track spans, the two panels at each end of the bottom chords shall be riveted members.

Eye-Bars

139. The thickness of an eye-bar shall be not less than one-eighth of the width nor less than 1 inch, and not greater than 2 inches. The cross-sectional area of the head through the center of the pin hole shall exceed that of the body of the bar by at least 37½ per ecnt. The form of the head shall be submitted to the Engineer for approval before the bars are made. The diameter of the pin shall be not less than seven-eighths of the width of the widest bar attached.

Packing

140. The eye-bars of a set shall be packed symmetrically about the plane of the truss and as nearly parallel as practicable. In no case shall the inclination of any bar to the plane of the truss exceed 1/16 inch to the foot. They shall be packed close, held against lateral movement, and so arranged that bars in the same panel will not be in contact.

Gusset Plates

141. The thickness of gusset plates connecting the chords and web members of the truss shall be proportionate to the stress to be transferred, but shall not be less than ½ inch.

Facilities for Lifting Span

142. Provision shall be made for lifting the span at the ends.

Masonry Plates

143. Masonry plates shall not be less than one inch thick.

(X) VIADUCTS

Type of Viaduct

144. Viaducts shall consist usually of alternate tower spans and free spans of plate girders or riveted trusses supported on bents. The tower spans usually shall be not less than 30 feet long.

Bents and Towers

145. Viaduct bents shall be composed preferably of two supporting columns, and the bents usually shall be united in pairs to form towers. In towers having more than two vertical panels, horizontal bracing shall be placed at alternate intermediate panel points. In double track towers, provisions shall be made for the transmission of the longitudinal force to both sides.

Single Bents

146. Where long spans are supported on short single bents, such bents shall have hinged ends, or else have their columns and anchorages proportioned to resist the bending stresses produced by changes in temperature.

Bottom Struts

147. The bottom struts of viaduct towers shall be proportioned for the calculated stresses, but in no case for less than one-fourth of the dead load reaction on one pedestal, considered as compressive stress. Provision shall be made in the column bearings for expansion of the tower bracing.

Batter

148. The columns usually shall have a batter transversely of one horizontal to six vertical for single track viaducts, or one horizontal to eight vertical for double track viaducts.

Depth of Girders

149. The depths of the girders in a viaduct preferably shall be uniform.

Spacing of Girders

150. In single track viaducts, the girder spacing usually shall be uniform throughout, and shall be determined by the spacing for the longest span in the viaduct, according to the rules specified for deck plate girder spans.

151. In double track viaducts, the girders under each track usually shall be spaced 6 feet 6 inches between centers, and the inner lines of girders shall be supported by cross-girders framed between and riveted to the posts.

Girder Connections and Bracing

152. The girders of tower spans shall be fastened at both ends to the tops of the posts or cross-girders. Girders between towers shall have one end riveted, and shall be provided with an effective expansion joint at the other end. No bracing or sway frame shall be common to abutting spans.

153. If neither of the girders under a track rests directly over a tower post, bracing shall be provided to carry the longitudinal force into the tower bracing without producing lateral bending stress in the cross-girders or posts.

Sole and Masonry Plates

154. Sole and masonry plates shall be not less than ¾ inch thick.

Anchorage for Towers

155. Anchor bolts for viaduct towers and similar structures shall be designed to engage a mass of masonry the weight of which is at least one and one-half times the uplift.

(XI) MATERIALS*

(a) STRUCTURAL AND RIVET STEEL

Process

156. The steel shall be made by the open-hearth process.

Chemical Composition

157. The steel shall conform to the following requirements as to chemical composition:

	Structural Steel	*Rivet Steel*
Phosphorus—		
Acid	not over 0.06 per cent	not over 0.04 per cent
Basic	not over 0.04 per cent	not over 0.04 per cent
Sulphur	not over 0.05 per cent	not over 0.045 per cent

Ladle Analyses

158. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer, and shall conform to the requirements specified in Section 157.

Check Analyses

159. Analyses may be made by the Engineer from finished material representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified in Section 157 by more than 25 per cent.

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*Specifications for materials conform to A.S.T.M. Standards, Serials A7-24, A27-24 and A48-18, except as to the footnote to Table II, Section 180, and minimum yield point for cast steel, Section 184. Section 164 is in agreement with the A.S.T.M. Standard Methods for Testing, Serial E1-18.

Physical Properties

160. The steel shall conform to the following requirements as to physical properties, except as specified in Sections 161 and 162:

Properties Considered	*Structural Steel*	*Rivet Steel*
Tensile strength, lb. per sq. in.	55,000 to 65,000*	46,000 to 56,000
Yield point, minimum lb. per sq. in.	30,000†	25,000†
Elongation in 8 inches, minimum per cent	$\frac{1{,}500{,}000^{\ddagger}}{\text{tens. strength}}$	$\frac{1{,}500{,}000}{\text{tens. strength}}$
Elongation in 2 inches, minimum per cent	22	......

*See Section 161.
†In no case less than 0.5 tensile strength.
‡See Section 162.

161. In order to meet the required tensile strength of full-size annealed eye-bars, the Engineer may determine the tensile strength to be obtained in specimen tests, the range not to exceed 14,000 lb. per sq. in. and the maximum not to exceed 74,000 lb. per sq. in. The material shall conform to the requirements as to physical properties other than tensile strength, specified in Sections 160, 162 and 166.

162. For structural steel over ¾ inch or under, $\frac{5}{16}$ inch thick, deductions from the percentage of elongation in 8 inches specified in Section 160, shall be made as follows:

Over ¾ inch thick, deduct 0.25 per cent for each $\frac{1}{32}$ inch above ¾ inch, to a minimum of 18 per cent.
Under $\frac{5}{16}$ inch thick, deduct 1.25 per cent for each $\frac{1}{32}$ inch under $\frac{5}{16}$ inch.

Yield Point

163. The yield point shall be determined by the drop of the beam of the testing machine.

Speed of Testing Machine

164. The cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but in no case shall the values given in the following table be exceeded:

Gage Length of Specimen	*Maximum Cross-head Speed (inches per minute) in determining:*	
	Yield Point	*Tensile Strength*
2 in.	0.5	2.0
8 in.	2.0	6.0

Bend Tests

165. The test specimens (except as specified in Sections 166 and 167) shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows:

(a) For material ¾ inch or less in thickness, flat on itself.
(b) For material more than ¾ inch to and including 1¼ inches in thickness, around a pin the diameter of which is equal to the thickness of the specimen.
(c) For material more than 1¼ inches in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

166. The test specimens for eye-bar flats shall bend cold through 180 degrees without cracking on the outside of the bent portion as follows:

(a) For material ¾ inch or less in thickness, around a pin the diameter of which is equal to the thickness of the specimen.
(b) For material more than ¾ inch to and including 1¼ inches in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.
(c) For material more than 1¼ inches in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

167. The test specimens for rivet steel shall bend cold through 180 degrees flat on themselves without cracking on the outside of the bent portion.

Test Specimens

168. Test specimens shall be prepared for testing from material in its rolled or forged condition except as specified in Section 169.

169. Test specimens for annealed material shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

170. Test specimens shall be taken longitudinally and, except as specified in Sections 171 and 172, shall be of the full thickness or section of material as rolled.

Test specimens for plates, shapes, and flats may be machined to the form and dimensions shown in Fig. 4, or with both edges parallel. Bend test specimens for eye-bar flats may have three rolled sides.

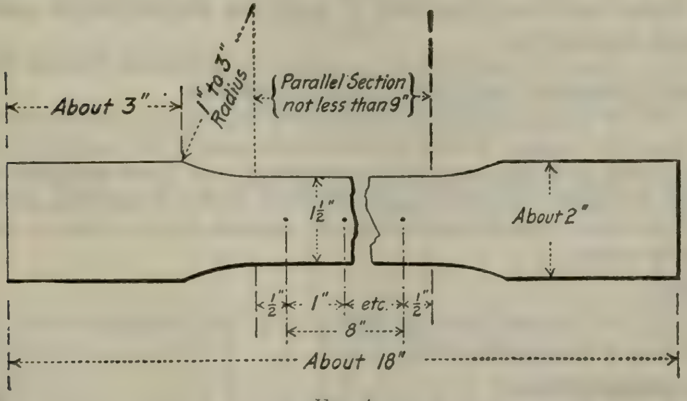

FIG. 4

171. Tension test specimens for material over 1½ inches in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of at least ¾ inch for a length of at least 9 inches, or they may conform to the dimensions shown in Fig. 5.

Bend test specimens for material over 1½ inches in thickness or diameter except eye-bar flats, pins and rollers, may be machined to a thickness or diameter of at least ¾ inch or to a section 1 by ½ inch.

172. Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 5, and bend test specimens shall be 1 by ½ inch in section.

Test specimens for pins and rollers shall be so taken that the axis will be 1 inch from the surface.

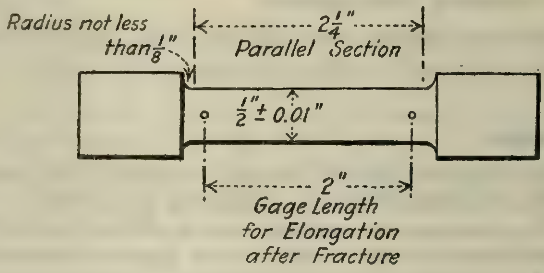
Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2"
Gage Length for Elongation after Fracture

Fig. 5

Note.—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form that will fit the holders of the testing machine in such a way that the load will be axial.

173. The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over 1/16 inch.

Number of Tests

174. One tension and one bend test shall be made from each melt; except that if material from one melt varies ⅜ inch or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

175. If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

176. If the percentage of elongation of any tension test specimen is less than that specified in Section 160, and any part of the fracture is more than ¾ inch from the center of the gage length of a 2-inch specimen or is outside the middle third of the gage length of an 8-inch specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Finish

177. The finished material shall be free from injurious defects and shall have a workmanlike finish.

Identification Marks

178. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on the finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked by stamping if practicable, on each test specimen.

Inspection

179. The Inspector representing the Company shall have free entry, at all times while work on the contract of the Company is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the Inspector free of cost all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Inspections and tests (except check analyses) shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

The manufacturer shall furnish, without charge, the test specimens as specified herein, and the labor, testing machines and tools necessary to make the specimen and full-size tests.

Permissible Variations in Weight and Thickness

180. The cross-section or weight of any piece of steel shall not differ more than 2.5 per cent from that specified, except in the case of sheared plates, which shall be covered by the following permissible variations:

(a) When ordered to weight per square foot, the weight of each lot in each shipment shall not vary from the weight ordered more than the amount given in Table I. The term "lot" as applied to Table I means all of the plates of each group width and group weight.

(b) When ordered to thickness, the thickness of each plate shall not vary more than 0.01 inch under that ordered. The overweight of each lot in each shipment shall not exceed the amount given in Table II. The term "lot" as applied to Table II means all of the plates of each group width and group thickness.

NOTE—Steel is assumed to weigh 0.2833 lb. per cu. in.

Table I.—Permissible Variation of Rectangular Plates Ordered to Weight

ORDERED WEIGHT, Lb. per Sq. Ft.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS																	
	Under 48 In.		48 to 60 In., Excl.		60 to 72 In., Excl.		72 to 84 In., Excl.		84 to 96 In., Excl.		96 to 108 In., Excl.		108 to 120 In., Excl.		120 to 132 In., Excl.		132 In. or Over	
	Over.	Under	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	..
5 to 7.5, excl	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	..
7.5 to 10, excl	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	..
10 to 12.5, excl	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 to 15, excl	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 to 17.5, excl	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 to 20, excl	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 to 25, excl	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 to 30, excl	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 to 40, excl	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3

NOTE—The weight per square foot of individual plates shall not vary from the ordered weight by more than one and one-third times the amount given in this table.

Table II.—Permissible Overweights of Rectangular Plates Ordered to Thickness

ORDERED THICKNESS, Inches.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS								
	Under 48 In.	48 to 60 In., Excl.	60 to 72 In., Excl.	72 to 84 In., Excl.	84 to 96 In., Excl.	96 to 108 In., Excl.	108 to 120 In., Excl.	120 to 132 In., Excl.	132 In. or Over
Under 1/8	9	10	12	14	....	....	....	....	....
1/8 to 3/16, excl.	8	9	10	12	....	....	....	....	....
3/16 to 1/4, excl.	7	8	9	10	12	....	....	....	....
1/4 to 5/16, excl.	6	7	8	9	10	12	14	16	19
5/16 to 3/8, excl.	5	6	7	8	9	10	12	14	17
3/8 to 7/16, excl.	4.5	5	6	7	8	9	10	12	15
7/16 to 1/2, excl.	4	4.5	5	6	7	8	9	10	13
1/2 to 5/8, excl.	3.5	4	4.5	5	6	7	8	9	11
5/8 to 3/4, excl.	3	3.5	4	4.5	5	6	7	8	9
3/4 to 1, excl.	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

NOTE—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third times the amount given in this table.

Rejection

181. Unless otherwise agreed, any rejection based on analyses made in accordance with Section 159 shall be reported within five working days from the receipt of samples.

Material which shows any injurious defect subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Specimens analyzed in accordance with Section 159, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

(b) CAST STEEL

Process

182. Cast steel shall be made by the open-hearth, the electric furnace or the crucible process.

Heat Treatment

183. Castings shall be annealed.

Chemical and Physical Properties

184. Test specimens of cast steel shall conform to the following requirements as to chemical composition and physical properties:

	Maximum Phosphorus per cent	*Maximum Sulphur per cent*	*Min. Ten. Strength lb. per sq. in.*	*Minimum Yield Point lb. per sq. in*	*Min. Elongation in 2 in. per cent*	*Minimum Reduction of Area per cent*
Basic	0.05	0.06	60,000	30,000	24	35
Acid	0.06					

Ladle Analyses

185. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from drillings taken at least ¼ inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the Engineer.

Check Analyses

186. Check analyses may be made by the Engineer from a broken tension or bend test specimen. The phosphorus and sulphur content thus determined shall not exceed that specified in Section 184 by more than 20 per cent. Drillings for analysis shall be taken not less than ¼ inch beneath the surface.

Yield Point

187. The yield point shall be determined by the drop of the beam of the testing machine. The speed of the machine shall conform to the requirements of Section 164.

Bend Tests

188. The test specimen shall bend cold through 120 degrees around a one-inch pin without cracking on the outside of the bent portion.

Test Specimens

189. Tension and bend test specimens shall be taken from test bars cast attached to the castings where practicable. If the design of the castings is such that test bars should not be attached to the castings, the test bars shall be cast attached to special blocks, of which a sufficient number shall be provided for each lot of castings. Test bars from which tension and bend test specimens are to be taken shall remain attached to the castings or blocks they represent through annealing and until presented for inspection. Test bars shall be provided in sufficient numbers to furnish the tests required in Section 192.

190. Tension test specimens shall conform to the dimensions shown in Fig. 5. The ends shall be of a form to fit the holders of the testing machine in such a way that the load will be axial.

191. Bend test specimens shall be machined to 1 inch by ½ inch in section with corners rounded to a radius not over $\frac{1}{16}$ inch.

Number of Tests

192. One tension test and, when specified, one bend test shall be made from each melt in each annealing charge and, when specified, from each casting weighing 500 lb. or more.

193. If the percentage of elongation of any tension test specimen is less than that specified in Section 184 and any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

194. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-anneal such lot not more than twice and retests shall be made as specified in Section 184.

Workmanship and Finish at Foundry

195. The castings shall conform substantially to the drawings and shall be made in a workmanlike manner. The castings shall be free from injurious defects.

Inspection at Foundry

196. Tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

197. Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

(c) CAST IRON

Process

198. Cast iron shall be of tough gray iron, and shall be made by the cupola process.

Finish

199. Castings shall be true to pattern and free from excessive shrinkage. They shall be free from cracks, cold shuts, blow holes and other flaws.

Chemical Composition

200. The sulphur content of cast iron shall not exceed the following:

Light castings	0.10 per cent
Medium castings	0.10 per cent
Heavy castings	0.12 per cent

Drillings taken from the fractured ends of the transverse test bars shall be used for the sulphur determinations. One determination shall be made from each set of bars.

Classification

201. Castings shall be classified as light, medium and heavy.

(a) Light castings are those having any section less than ½ inch thick.
(b) Heavy castings are those having no section less than two inches thick.
(c) Medium castings are those not included in either of the classes (a) or (b).

Test Bar

202. Tests shall be made on the "Arbitration Test Bar" of the American Society for Testing Materials, as shown by Fig. 1, Serial A48-18.

Tension Tests

203. Tension tests will be made only when specified by the Engineer and at the expense of the Company.

Number of Tests

204. Two sets of two test bars each shall be cast from each melt in thoroughly dried green sand moulds, one set from the first iron poured and the other set from the last iron poured. If the melt exceeds 20 tons, an additional set of two bars shall be cast from each additional 20 tons or fraction thereof.

Transverse Tests

205. A transverse test of each bar cast shall be made. The supports shall be spaced 12 inches apart and the load applied at the middle. The load on the test bar at rupture shall be not less than the following:

Light castings	2500 pounds
Medium castings	2900 pounds
Heavy castings	3300 pounds

The deflection at rupture shall in no case be less than 0.10 inch. The rate of application of the load shall be such that a central deflection of 0.10 is produced in from 20 to 40 seconds.

(XII) WORKMANSHIP

Class of Work

206. The work shall be "Punched Work" or "Reamed Work" as stipulated.

General

207. The workmanship and finish shall be equal to the best general practice in modern bridge shops. Material at the shops shall be kept clean and protected from the weather as far as practicable.

Straightening Material

208. Rolled material, before being laid off or worked, must be straight. If straightening or flattening is necessary, it shall be done by methods that will not injure the material. Sharp kinks and bends may be cause for rejection.

Finish

209. Shearing and chipping shall be neatly and accurately done and all portions of the work exposed to view shall be neatly finished.

Punched Work

210. In punched work, holes in material whose thickness is not greater than the diameter of the rivets plus ⅛ inch, may be punched full size. Holes in material of greater thickness shall be drilled.

Reamed Work

211. In reamed work, holes in material ⅞ inch thick or less, used for lateral, longitudinal and sway bracing, lacing, stay plates and diaphragms, may be punched full size.

212. Holes in other material ¾ inch thick or less shall be sub-punched and reamed.

213. Holes in other material more than ¾ inch thick shall be drilled.

Punched Holes

214. Full-size punched holes shall be $\frac{1}{16}$ inch larger than the nominal diameter of the rivets. The diameter of the die shall not exceed the diameter of the punch by more than $\frac{3}{32}$ inch. If any holes must be enlarged to admit the rivets, they shall be reamed. Holes must be clean cut, without torn or ragged edges. Poor matching of holes may be cause for rejection.

Sub-Punched and Reamed Holes

215. In sub-punched and reamed work, the holes shall be punched $\frac{3}{16}$ inch smaller and, after assembling, reamed $\frac{1}{16}$ inch larger than the nominal diameter of the rivet. The diameter of the punch used shall be $\frac{3}{16}$ inch smaller than the nominal diameter of the rivet and the diameter of the die not more than $\frac{3}{32}$ inch larger than the diameter of the punch. Outside burrs shall be removed with a tool making a $\frac{1}{16}$-inch fillet.

Accuracy of Punching in Reamed Work

216. In sub-punched and reamed work, the punching shall be so accurately done that, after assembling and before reaming, a cylindrical pin ⅛ inch smaller in diameter than the nominal size of the punched hole may be entered, perpendicular to the face of the member, without drifting, in at least 75 of any group of 100 contiguous holes in the same plane. If this requirement is not fulfilled, the badly punched pieces shall be rejected. If any hole will not pass a pin $\frac{3}{16}$ inch smaller in diameter than the nominal size of the punched hole, this shall be cause for rejection.

Reaming After Assembling

217. Reaming shall be done after the pieces forming a built member are assembled and so firmly bolted together that the surfaces are in close contact. Before riveting, they shall be taken apart, if necessary, and any shavings removed. When it is necessary to take the members apart for shipping or handling, the pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No interchange of reamed parts will be permitted.

Accuracy of Reaming and Drilling

218. When holes are reamed or drilled, 85 of any group of 100 contiguous holes in the same plane shall, after reaming or drilling, show no offset greater than $\frac{1}{32}$ inch between adjacent thicknesses of metal.

Reamed Holes

219. Reamed holes shall be cylindrical, perpendicular to the member, and not more than $\frac{3}{32}$ inch larger than the nominal diameter of the rivets. Reamers preferably shall not be directed by hand. Outside burrs shall be removed with a tool making a $\frac{1}{16}$-inch fillet.

Drilled Holes

220. Drilled holes shall be $\frac{1}{16}$ inch larger than the nominal size of the rivet. Burrs on the outside surfaces shall be removed.

Assembling for Drilling

221. Connecting parts requiring drilled holes shall be assembled and securely held together while being drilled.

Shop Assembling

222. The parts of riveted members shall be well pinned and firmly drawn together with bolts before riveting is commenced. The drifting done during assembling shall be only such as to bring the parts into position, and not sufficient to enlarge the holes or distort the metal. Surfaces in contact shall be painted. Bolts in field connection holes shall be left in place.

Field Connections

223. Solid floor sections shall be assembled to the girders or trusses, or to suitable frames, in the shop, and the end connections made to fit.

224. In reamed work, riveted trusses and skew portals shall be assembled in the shop, the parts adjusted to line and fit, and the holes for field connections drilled or reamed while so assembled. Holes for other field connections, except those in lateral, longitudinal and sway bracing, shall be drilled or reamed in the shop with the connecting parts assembled, or else drilled or reamed to a metal template.

225. In punched work, the field connections (except those in lateral, longitudinal and sway bracing) shall be reamed to metal templates.

Match-Marking

226. Connecting parts assembled in the shop for the purpose of reaming or drilling holes in field connections shall be match-marked, and a diagram showing such marks shall be furnished the Engineer.

Rivets

227. The size of rivets called for on the plans shall be the size of the rivet before heating.

228. Rivet heads, when not countersunk or flattened, shall be of approved shape and of uniform size for the same diameter of rivet. Rivet heads shall be full, neatly made, concentric with the rivet holes, and in full contact with the surface of the member.

Riveting

229. Rivets shall be heated uniformly to a light cherry red and driven while hot. Rivets, when heated and ready for driving, shall be free from slag, scale, and carbon deposit. When driven, they shall completely fill the holes. Loose, burned, or otherwise defective rivets shall be replaced. In removing rivets, care shall be taken not to injure the adjacent metal, and if necessary, they shall be drilled out. Caulking or re-cupping will not be permitted.

230. Rivets shall be driven by direct-acting riveters where practicable. The riveters shall retain the pressure after the upsetting is completed.

231. When necessary to drive rivets with a pneumatic riveting hammer, a pneumatic bucker shall be used for holding up, when practicable.

Field Rivets

232. Field rivets shall be furnished in excess of the nominal number required to the amount of 15 per cent plus ten rivets, for each size and length.

233. Field rivets shall be carefully selected, and shall be free from fins on the under side of the head.

Turned Bolts

234. Where turned bolts are used to transmit shear, the holes shall be reamed parallel and the bolts shall make a tight fit with the threads entirely outside of the holes. A washer not less than ¼ inch thick shall be used under each nut.

Planing Sheared Edges

235. Sheared edges of material more than ⅝ inch thick and carrying calculated stress shall be planed to a depth of ¼ inch. Re-entrant cuts shall be filleted before cutting.

Lacing Bars

236. The ends of lacing bars shall be neatly rounded, unless otherwise called for.

Fit of Stiffeners

237. Stiffeners under the top flanges of deck girders and at all bearing points shall be milled or ground to bear against the flange angles. Other stiffeners must fit sufficiently tight against the flange angles to exclude water after being painted. Fillers and splice plates shall fit within ¼ inch at each end.

Web Plates

238. Web plates of girders which have no cover plates may be ⅛ inch above or below the backs of the top flange angles. Web plates of girders which have cover plates may be ½ inch less in width than the distance back to back of flange angles.

239. When web plates are spliced, not more than ⅜ inch clearance between ends of plates will be allowed.

Facing Floor Beams, Stringers and Girders

240. Floor beams, stringers and girders having end connection angles shall be made of exact length after the connection angles are riveted. If facing is necessary, the thickness of the angles shall not be reduced more than ⅛ inch at any point.

Finished Members

241. Finished members shall be true to line and free from twists, bends and open joints.

Abutting Joints

242. Abutting joints in compression members and girder flanges, and where so specified on the drawings, in tension members, shall be faced

and brought to an even bearing. Where joints are not faced, the opening shall not exceed ¼ inch.

Eye-Bars

243. Eye-bars shall be straight, true to size, and free from twists, folds in the neck or head, and other defects. The heads shall be made by upsetting, rolling or forging. Welding will not be allowed. The form of the heads will be determined by the dies in use at the works where the eye-bars are made, if satisfactory to the Engineer. The thickness of the head and neck shall not overrun more than 1/16 inch for bars 8 inches or less in width, ⅛ inch for bars more than 8 inches and not more than 12 inches in width, and 3/16 inch for bars more than 12 inches in width.

244. Eye-bars which are to be placed side by side in the structure shall be bored so accurately that, upon being placed together, the pins will pass through the holes at both ends at the same time without driving. Eye-bars shall have both ends bored at the same time.

Annealing

245. Eye-bars shall be annealed by heating uniformly to the proper temperature followed by slow and uniform cooling. Proper instruments shall be provided for determining at all times the temperature of the bars.

246. Other steel which has been partially heated shall be annealed except where used in minor parts.

Boring Pin Holes

247. Pin holes shall be bored true to gage, smooth, straight, at right angles with the axis of the member and parallel with each other, unless otherwise required. The variation from the specified distance from outside to outside of pin holes in tension members, or from inside to inside of pin holes in compression members, shall not exceed 1/32 inch. In built-up members the boring shall be done after the member is riveted.

Boring Pins

248. Pins more than 9 inches in diameter shall have a hole bored longitudinally through the center of each not less than 2 inches in diameter.

Pin Clearances

249. The difference in diameter between the pin and the pin hole shall be 1/50 inch for pins up to 5 inches in diameter, and 1/32 inch for larger pins.

Pins and Rollers

250. Pins and rollers shall be accurately turned to gage and shall be straight, smooth and free from flaws.

Screw Threads

251. Screw threads shall make close fits in the nuts and shall be U.S. Standard, except that for pin ends of diameters greater than 1⅜ inches, they shall be made with six threads to an inch.

Welds

252. Welds in steel will not be allowed, except to remedy minor defects.

Forging Pins

253. Pins more than 7 inches in diameter shall be forged and annealed.

Bearing Surfaces Planed

254. The top and the bottom surfaces of base and cap plates of columns and pedestals, except those in contact with masonry, shall be planed, or hot-straightened, and parts of members in contact with them shall be faced to fit. Connection angles for base plates and cap plates shall be riveted to compression members before the members are faced.

255. Sole plates of plate girders shall have full contact with the girder flanges. Sole plates and masonry plates shall be planed or hot-straightened. Cast pedestals shall be planed on the surfaces in contact with steel and shall have the bottom surfaces resting on masonry rough finished.

Pilot Nuts

256. Two pilot nuts and two driving nuts shall be furnished for each size pin, unless otherwise specified.

(XIII) WEIGHING AND SHIPPING

Weight Paid for

257. The payment for pound price contracts shall be based on the scale weight of the metal in the fabricated structure, including field rivets shipped. The weight of the field paint and cement, if furnished, boxes and barrels used for packing, and material used for staying or supporting members on cars, shall be excluded.

Variation in Weight

258. If the weight of any member is more than 2½ per cent less than the computed weight, it may be cause for rejection.

259. The greatest allowable variation of the total scale weight of any structure from the weights computed from the approved shop drawings shall be 1½ per cent. Any weight in excess of 1½ per cent above the computed weight shall not be paid for by the Company.

Computed Weight

260. The weight of steel shall be assumed at 0.2833 lb. per cubic inch.

261. The weights of rolled shapes, and of plates up to and including 36 inches in width, shall be computed on the basis of their nominal weights and dimensions, as shown on the approved shop drawings, deducting for copes, cuts and open holes.

262. The weights of plates wider than 36 inches shall be computed on the basis of their dimensions, as shown on the approved shop drawings, deducting for cuts and open holes. To this shall be added one-half of the allowed percentages of overrun in weight given in Section 180.

263. The weight of heads of shop driven rivets shall be included in the computed weight.

264. The weights of castings shall be computed from the dimensions shown on the approved shop drawings, with an additional 10 per cent for fillets and overrun.

Weighing of Members

265. Finished work shall be weighed in the presence of the Inspector, if practicable. The Contractor shall furnish satisfactory scales and do the handling of the material for weighing.

Marking and Shipping

266. Members weighing more than 5 tons shall have the weight marked thereon. Bolts and rivets of one length and diameter, and loose nuts or washers of each size, shall be packed separately. Pins, other small parts, and small packages of bolts, rivets, washers and nuts shall be shipped in boxes, crates, kegs or barrels, but the gross weight of any package shall not exceed 300 pounds. A list and description of the contained material shall be plainly marked on the outside of each package, box or crate.

267. Long girders shall be so loaded and marked that they will arrive at the bridge site in position for erection without turning.

268. Anchor bolts, washers and other anchorage or grillage materials shall be shipped in time for them to be built into the masonry.

(XIV) SHOP PAINTING

Shop Cleaning and Painting

269. Unless otherwise specified, steel work, after it has been accepted by the Inspector and before leaving the shop, shall be thoroughly cleaned and given one coat of approved paint, applied in a workmanlike manner and well worked into joints and open spaces. Cleaning shall be done with steel brushes, hammers, scrapers and chisels, or by the other equally effective means. Oil, paraffin and grease shall be removed by wiping with benzene or gasoline. Loose dirt shall be brushed off with a dry bristle brush before the paint is applied.

Surfaces in Contact

270. Surfaces coming in contact shall be cleaned and given one coat of paint on each surface before assembling.

Erection Marks

271. Erection marks shall be painted on painted surfaces.

Painting in Damp or Freezing Weather

272. Painting shall not be done in damp or freezing weather except under cover, and the steel must be free from moisture or frost when the paint is applied. Material painted under cover in damp or freezing weather shall be kept under cover until the paint is dry.

Mixing of Paint

273. Paint shall be thoroughly mixed before applying, and the pigments shall be kept in suspension.

Machine Finished Surfaces

274. Machine finished surfaces of steel (except abutting joints and base plates) shall be coated with white lead and tallow, applied hot as soon as the surfaces are finished and accepted by the Inspector.

(XV) SHOP INSPECTION

Facilities for Inspection

275. Facilities for inspection of material and workmanship in the shop shall be furnished by the Contractor to the Inspector, and the Inspector shall be allowed free access to the necessary parts of the work.

Material Orders and Shipping Statements

276. The Contractor shall furnish the Engineer with as many copies of material orders and shipping statements as the Engineer may direct. The weights of the individual members shall be shown.

Notice of Beginning Work

277. The Contractor shall give ample notice to the Engineer of the beginning of work at the shop, so that inspection may be provided. No work shall be done before the Engineer has been notified.

Cost of Inspection

278. The Contractor shall afford the Engineer, free of cost, all reasonable facilities to satisfy him that the material is being furnished and the work done in accordance with these specifications.

Inspector's Authority

279. The Inspector shall have the power to reject materials or workmanship which do not meet the requirements of these specifications. In cases of dispute, the Contractor may appeal to the Engineer, whose decision shall be final.

Rejections

280. The acceptance of any material or finished members by the Inspector shall not be a bar to their subsequent rejection, if found defective.

281. Rejected material and workmanship shall be replaced promptly or made good by the Contractor.

(XVI) FULL-SIZE TESTS

Full-Size Tests of Eye-Bars

282. The number and size of the bars to be tested shall be stipulated by the Engineer before the mill order is placed. The number shall not

exceed 5 per cent of the whole number of bars ordered, with a minimum of two bars on small orders.

283. The test bars shall be of the same section as the bars to be used in the structure and of the same length if within the capacity of the testing machine. They shall be selected by the Inspector from the finished bars preferably after annealing. Test bars representing bars too long for the testing machine shall be selected from the full length bar material after the heads on one end have been formed and shall have the second head formed upon them after being cut to the greatest length which can be tested.

284. Full-size tests of eye-bars shall show a yield point of not less than 29,000 pounds per square inch, an ultimate strength of not less than 54,000 pounds per square inch, and an elongation of not less than 10 per cent in a length of 20 feet measured in the body of the bar. The fracture shall show a silky or finely granular structure throughout.

285. If a bar fails to meet the requirements of Section 284, two additional bars of the same size and from the same mill heat shall be tested. If the failure of the first test bar is on account of the character of the fracture only, the bars represented by the test may be reannealed before the additional bars are tested.

286. If two of the three bars tested fail, the bars of that size and mill heat shall be rejected.

287. A failure in the head of a bar shall not be cause for rejection if the other requirements are fulfilled.

288. A record of the annealing charges shall be furnished the Engineer showing the bars included in each charge and the treatment they receive.

289. Bars thus tested which meet the requirements of the specifications shall be paid for by the Company at the same unit prices as the bars accepted. Bars which fail to meet the requirements of the specifications, and all bars rejected as a result of tests, shall be at the Contractor's expense.

(These specifications are available in pamphlet form with a complete index.)

[2]SPECIFICATIONS FOR MOVABLE RAILWAY BRIDGES

FOREWORD

The purpose of the Committee in writing these specifications was to formulate specific and detailed rules for the design and manufacture of movable railway bridges, as a guide to both the designer and the shop, rather than to confine the specifications to a statement of principles or to limit them to rules defining the duties of the contractor. The intention was to describe the best general practice in the accepted types now in use for standard American and Canadian railways and to advance the causes of good design and workmanship. The requirements of light and branch railways and foreign practice have not been considered.

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[2] Adopted, Vol. 23, 1922, pp. 169, 1052.

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(I) PROPOSALS AND GENERAL REQUIREMENTS

101. The current Specifications for Steel Railway Bridges of the American Railway Engineering Association shall apply to movable bridges except as provided otherwise herein.

Responsibility

102. Unless otherwise provided, the fabricating contractor shall be responsible for the complete installation of the superstructure and the operation of the moving span as far as pertains to the materials, workmanship, and erection; and the designing of parts and details which are not covered by the proposal plans. The Contractor shall furnish and erect the structure ready for the application of power for its operation and to receive trains.

Time of Opening

103. The normal time for opening the bridge after the ends are released shall be as specified on the proposal drawings for both the main and the auxiliary powers.

Machinery Drawings

104. Unless otherwise provided, the Contractor shall furnish an outline drawing of the machinery on which are shown the forces acting on the gear teeth, the twisting moment and the bending moment on shafts, and other information necessary for computing the strength of the machinery parts. The Contractor shall make an assembly drawing and detail drawings of the machinery. These drawings shall be so complete that the machinery parts may be duplicated without reference to patterns, other drawings, or individual shop practice.

Torque Curves

105. The Contractor shall show by curves the torque to be exerted at the motor pinion as follows:

(a) Torque curves for acceleration and for retardation.
(b) A torque curve for the frictional resistance. The torque for starting friction shall not be combined with the torque for acceleration.
(c) A torque curve for any unbalanced condition of the structure.
(d) A torque curve for the wind loads.
(e) A torque curve showing the greatest resultant combination of resistances acting at one time. The torque curves of the motors under various operating conditions shall be superimposed on this curve.

Weight and Center of Gravity

106. The Contractor shall determine the weight and (where necessary) the location of the center of gravity of the moving span, including parts attached thereto; also of the counterweights, including their frame work. These determinations shall be based on weights carefully computed from shop plans. The computations, accompanied by the weight bills, shall be submitted to the Company in form for verification.

Houses

107. The Contractor shall furnish and build the machinery house. The house for the operator and the signal devices shall be built by the Contractor or the Company as may be stipulated.

Signals and Interlocking

108. The Company will furnish and install the railway signal system, including the master lever and the devices nceessary for interlocking the signal system with the moving span. The Contractor shall furnish and install the devices necessary for interlocking the parts of the bridge machinery with each other and for connection to the master lever. The operating machinery and the electrical parts shall be so designed that the signal system may readily be installed and attached.

Warning Lights

109. The Contractor shall furnish and install (including wiring) on the moving span and piers, navigation lights and other signals required by the United States Government or other authorities, and shall provide suitable means of access to such lights.

Wrenches

110. Two sets of wrenches to fit heads and nuts of bolts for the machinery shall be furnished by the Contractor.

Defects

111. If any defects due to faulty workmanship or erection, or defective material, or design for which the Contractor is responsible, are found within one year after the final test and acceptance, the Contractor shall remedy such defects at his own cost. If necessary, the Company may remedy such defects at the expense of the Contractor.

Classification of Parts

112. The parts of the bridge shall be classified as follows, and unless otherwise stipulated, paid for as indicated:

(a) Structural steel, by the pound.
(b) Machinery, by the pound.
(c) Engines, boilers and tanks, a lump sum.
(d) Electrical equipment, a lump sum.
(e) Wire ropes and wire rope attachments, by the pound.
(f) Houses for machinery and for operators, a lump sum.
(g) Sheaves for counterweights, by the pound.
(h) Metal in counterweights, by the pound.
(i) Concrete, by the cubic yard.
(j) Timber deck and track, by the linear foot of track.
(k) Timber walks, by the thousand feet, board measure. Nominal dimensions of timbers to govern.
(l) Balancing chains, by the pound.

Parts not classified under headings (b) to (l) inclusive, shall be classified under (a), structural steel.

Payment by the pound shall be based on scale weights of the finished material.

113. Parts included in the different classes shall be:

(a) Structural Steel: In addition to the moving span, any parts of rolled or cast steel which can be fabricated by the common shop methods of punching, reaming, drilling, boring, shearing, planing, bending, etc., usual for stationary structures.

Rim girders in swing bridges, segmental girders in rolling bascule bridges and the girders on which they roll, parts supporting the machinery, counterweight frames, counterweight trusses, operating struts, towers, steel framing and plates in houses for machinery and operators, hand rails, stairways, ladders, and specially fabricated track rails, shall be classified as structural steel.

(b) MACHINERY: Winding drums, tread plates, pedestals, wedge bases, center pivot stands, pistons and their cylinders, eccentrics, pivots, trunnions and their cast supports, shafts, spools, gears, racks, bearings, couplings, clutches, brakes (unless part of the motors), discs, cast sheaves and wheels, rollers, cast roller treads and guides, worm gearing, valves, pins about whose axes the connecting members rotate, screws, wedges, toggles, bridge locks, rail locks, indicators, whistles, cranks, axles, hooks, wrenches, turned bolts attaching machinery parts, and similar parts which require machine shop work and which are not included in any other class.

Machinery parts attached to structural parts shall be weighed separately.

(c) ENGINES, BOILERS AND TANKS: Internal combustion engines, steam engines, pumps, compressors, anchor bolts, steam boilers and stacks, air compressor tanks and other tanks, with their fittings and piping.

(d) ELECTRICAL EQUIPMENT: The switchboard with its attachments and electrical parts beyond (whether on or off the moving span), such as motors, controllers, solenoids, conductors, conduits and their fittings, lamps, blowouts, cut-offs, circuit breakers, contactors, switches, trolley poles, trolley wheels and contact shoes.

Electrical equipment carrying the current to the switchboard from the source of power will be covered by a separate contract.

(e) HOUSES FOR MACHINERY AND OPERATORS: All parts of such houses except steel framing and plates.

(f) WIRE ROPES AND WIRE ROPE ATTACHMENTS: Ropes with their attached sockets, and fastenings of the ropes to the trusses and counterweights, including pins and equalizing devices.

(g) COUNTERWEIGHT SHEAVES: Cast or built sheaves, together with their axles and bearings.

(h) METAL IN COUNTERWEIGHTS: Only cast iron and scrap metal used in counterweights.

(i) CONCRETE: Concrete and reinforcing bars used in counterweights, and concrete in pockets of column bases and similar places. No deductions shall be made for enclosed metal.

(j) TIMBER DECK AND TRACK: Placing and permanently fastening the timber deck and track. Unless otherwise specified the Company will furnish the deck and track material and fastenings, except rail-locks, specially fabricated rails, and special devices to hold the deck in place.

(k) TIMBER WALKS: Furnishing and placing lumber in walks, platforms, etc., together with nails, bolts, and other fastenings.

(l) BALANCING CHAINS: Chains and their fastenings used for balancing the counterweight ropes.

(II) GENERAL FEATURES OF DESIGN

Types

201. Movable bridges preferably shall be of the following types:

(a) Swing.
(b) Single leaf bascule.
(c) Vertical lift.

The type to be used will be determined by the Engineer. Pin connected trusses shall not be used.

Counterweight

202. The counterweight shall be sufficient to balance the moving span and its attachments in any position. In vertical lift bridges, the counterweight ropes shall be balanced by chains unless otherwise specified.

Aligning and Locking

203. Movable bridges shall be equipped with suitable mechanism to align them accurately and to lock them securely in position, so that they cannot be displaced either horizontally or vertically under the action of traffic. The operating mechanisms of end lifts and rail locks shall be independent.

Auxiliary Power

204. Bridges operated by mechanical power shall be equipped with auxiliary power. The auxiliary power shall be hand or mechanical, as determined by the Engineer.

Interlocking

205. The bridge operating devices shall permit interlocking with the signal system. They shall be so interlocked with each other that the operations, both for opening and closing the bridge, must be performed in a predetermined order.

Insulation of Track

206. The connections of parts in contact with the track shall be such as to prevent all possibility of short circuiting of track signals.

Houses for Machinery and Operators

207. If mechanical power is to be used for operating the bridge, a suitable house shall be provided for the machinery and the operator. The house shall be large enough for easy access to all machinery. The house shall be fireproof and weatherproof. There shall be at least one window in each side of the house.

The floor shall be built of concrete. It shall be smoke tight and have a non-slip surface.

If the operator is not located in the machinery house, or if the bridge is hand operated, a house shall be provided for him. The type of construction shall be the same as that specified for the machinery house, except that for hand-operated bridges with the house located off the bridge structure, fully fireproof construction will not be required.

Provision shall be made for the heating apparatus to be installed by the Company in the operator's house.

If stipulated, a 5-ton capacity hand operated overhead traveling crane shall be installed in the machinery house.

Stairways and Walks

208. Metal stairways, platforms, and walks with railings shall be provided, for access to the operator's house, machinery, trunnions, counterweights, lights, bridge seats, and similar parts. Ladders may be installed only where stairways are not feasible. In vertical lift bridges, ladders and walks shall be installed to give access to the moving span in any position from either tower. Hand railings shall be made of gas pipe not less than 1½-inch size. Stairways and ladders shall be of metal. The treads may be channels filled with concrete.

Materials Used

209. Materials in machinery and similar parts shall be as follows:

Rolled Steel or Forged Steel: For trunnions, shafts, axles, bolts, nuts, keys, cotters, pins, screws, worms, piston rods and crane hooks.

Shafts up to 6 inches in diameter may be either rolled or forged; shafts larger than this shall be forged. Shafts larger than 3½ inches in diameter shall not be cold rolled.

Forged Steel or Cast Steel: For rim girder tread plates, levers, cranks, connecting rods, and rollers.

Forged Steel: For pinions and equalizing levers.

Cast Steel: For pivot stands, couplings, wedges, wedge bearings, trailing wheels, end shoes, racks, tracks, winding drums, gears, brake wheels, sheaves on lift bridges, trunnion bearings and shaft bearings and hangers. Large sheaves may be built of structural steel and cast steel.

Tool Steel: For parts which require hardening or oil tempering, such as pivots, friction rollers, ball bearings and springs.

Phosphor-Bronze: For pivot discs, worm wheels, linings of the trunnion bearings of bascule and lift bridges, linings of other large bearings carrying heavy loads, and such gears and nuts as are required to be of bronze.

Phosphor-Bronze, Bronze, or Babbitt Metal: For the linings of journal bearings and of other rotating or sliding parts.

Cast Iron may be used for eccentrics, cylinders, pistons, fly-wheels, certain shaft bearings described below, journal boxes, and parts of motors which are usually made of cast iron. In power operated bridges, the permission to use cast iron shaft bearings applies only to line shaft bearings carrying the weight of the shafting only. Cast iron shall not be used for couplings, for trunnion supports of bascule or lift bridges, or in the pivots of swing bridges.

The balancing chains, which are hung below the counterweights in vertical lift bridges, shall be made of cast iron links connected by steel pins in cored holes.

Type of Center

210. The type of center to be used in swing bridges will be determined by the Engineer.

Center Bearing

211. Center bearing swing bridges shall be so designed that when the bridge is swinging, the entire weight of the moving span is carried on a center pivot, and when the bridge is closed, the trusses rest at the center on wedges. Adjustment for height shall be provided.

Rim Bearing

212. The load on the rim girder of a rim bearing or combined rim and center bearing swing bridge shall be distributed equally among the bearing points. The bearing points shall be spaced equally around the rim girder.

Rigid struts shall connect the rim girder to a center pivot firmly anchored to the pier. A strut shall be attached to the rim girder at each bearing point, and at intermediate points when required. No fewer than eight struts shall be used in any case.

The rim girder shall be so designed that the load will be properly distributed over the rollers. For calculating stresses in the girder, the loads shall be assumed to be distributed equally to all rollers. The span length shall be taken as the developed length of the girder between adjacent bearing points. This part of the girder shall be considered fixed at both ends. The girder shall be designed in accordance with the requirements for plate girders.

The lower track shall be strong enough to distribute the load on the rollers uniformly over the masonry.

Combined Bearing

213. In a combined rim and center bearing swing bridge, a definite portion of the load, not less than 15 per cent, shall be carried to the center by radial girders attached rigidly to the center and to the rim.

Shear Over Center

214. In swing bridges having a center truss panel, this panel shall be so designed that shear will not be carried past the center. The web members of such panel shall be strong enough, however, to make the bridge secure against longitudinal wind pressure when it is open.

(III) LOADS, UNIT STRESSES AND PROPORTIONING OF PARTS

Stresses in Swing Bridges

301. The stresses in trusses or girders of swing bridges continuous on three or four supports shall be calculated for the bridge in the following conditions:

1. Bridge open, or closed with ends just touching.
2. Bridge closed with ends lifted.

The computation of stresses shall be divided into the following cases:

Case I. Condition 1, dead load.

Case II. Condition 2, dead load, ends lifted to give positive reaction equal to the maximum negative reaction of the live load and impact plus 50 per cent of their sum.

Case III. Condition 1, live load on one arm as a simple span.

Case IV. Condition 2, live load on one arm, bridge as a continuous girder.

Case V. Condition 2, live load on both arms, bridge as a continuous girder.

The following combinations of these cases shall be used in determining the maximum stresses:

Case I alone.
Case I with Case III.
Case I with Case V.
Case II with Case IV.
Case II with Case V.

The stress sheet shall show the stresses in the different members for each of the foregoing cases, together with the combinations which give the greatest positive and negative stresses in each member.

In computing the live load stresses, the live load shall be considered as applied, either continuously or in detached parts, in such a manner as to produce the maximum stresses.

Impact

302. Stresses in structural parts which vary with the movement of the span (as in the case of a bascule bridge) shall be increased 20 per cent as an allowance for impact. This impact allowance shall not be combined with the live load stresses.

Stresses in structural parts caused by the machinery or by forces applied for moving or stopping the span, shall be increased 100 per cent as an allowance for impact.

The end floor beams of the moving span and the adjacent floor beams of the fixed spans shall be proportioned for a concentrated load of 75,000 lb. on each track, in addition to the specified live load and impact.

End Ties

303. The first two ties of the moving span and of the adjacent ends of the fixed spans shall be supported throughout their length, so that they will not be subjected to bending. The supports for these ties, if other than end floor beams, shall be proportioned for a concentrated load of 75,000 lb. on each track plus 150 per cent impact.

Reversal of Stress and Secondary Stresses

304. Structural members and their connections, subject to reversal of stress during the movement of the span, shall be proportioned as follows: Determine the resultant tensile stress and the resultant compressive stress, and increase each by 25 per cent of the smaller; then proportion the member to resist either increased resultant stress.

Secondary stresses occurring in connection with reversal of stress, and those in trusses of unusual form, shall be computed, and provided for in proportioning.

End Lift Reactions

305. The end lifting machinery of swing bridges shall be proportioned to exert an uplift equal to the maximum negative end reaction of the live load and impact plus 50 per cent of their sum.

The end bearings shall be proportioned for the maximum positive end reaction including impact.

The center wedges and supports shall be proportioned for the reaction of the live load and impact.

Rollers

306. The rollers of rim bearing or combined rim and center bearing swing bridges shall be proportioned for the dead load stresses when the bridge is swinging, and for the dead and live load and impact stresses when the bridge is closed.

In computing the load on the rollers, the rim girder shall be considered as distributing the load uniformly over a distance equal to twice the depth of the girder, back to back of flange angles. This distance shall be taken as symmetrical about the vertical through the point of application of the concentrated load.

Wind Load and Ice Load

307. In proportioning the members and determining the stability of the moving span and the towers of bascule bridges and vertical lift bridges when the span is in the open position, the wind pressure shall be assumed as 15 lb. a square foot, applied to the exposed surface of the floor and the two trusses as seen in elevation.

In determining the stability of swing bridges when open, the wind pressure shall be assumed as 2½ lb. a square foot acting on the horizontal projection of one arm.

In swing spans, the transverse balance wheels and their axles, bearings, and brackets shall be designed for an overturning wind pressure of 10 lb. a square foot of surface of the floor and the two trusses as seen in elevation.

For open deck bridges, the area of the floor exposed to wind and ice shall be taken as 85 per cent of the area of a quadrilateral, whose width is the distance center to center of trusses and whose length is that of the floor of the span. For bridges with solid floors, or with footwalks, the actual exposed floor surface shall be taken.

In proportioning the members and determining the stability of the bridge when closed, the assumed wind loads shall be in accordance with the Specifications for Steel Railway Bridges of the American Railway Engineering Association.

308. In proportioning the machinery and determining the power required for operation, the loads shall be assumed as applied in the following manner:

For bascule and unequal arm swing bridges, the machinery shall be proportioned to hold the span in any position with a wind load of 15 lb. a square foot on any vertical projection of the open bridge. In proportioning the machinery for this condition, the stresses specified herein may be increased one-half.

The machinery shall be proportioned and power provided to move the span under the following conditions:

(A) In the normal time for opening:

1. Bascule bridges and vertical lift bridges against frictional resistances, inertia, and a wind load of 2½ lb. a square foot on the floor area, acting normal to the floor.
2. Swing bridges against frictional resistances, inertia, and a wind load of 2½ lb. a square foot of the vertical projection of one arm.

(B) In one and one-half times the normal time for opening:

Bascule bridges and vertical lift bridges with an ice load of 2½ lb. a square foot of floor area in addition to the loads specified in (A).

(C) In twice the normal time for opening:

Bascule bridges and unequal arm swing bridges against frictional resistances, inertia, a wind load of 10 lb. a square foot of any vertical projection and an ice load of 2½ lb. a square foot on the floor area.

Machinery Resistances

309. In calculating the resistances to be overcome by the machinery, the resisting forces shall be reduced to a single force acting between the pinion and the operating rack, or in the operating cable. In determining this force, the following coefficients shall be used:

	For Starting	*For Motion*
For trunnion friction:		
(a) One or more complete rotations	0.135	0.09
(b) Less than one complete rotation	0.18	0.12
For friction on center discs	0.15	0.10
For rolling friction of bridges having rollers with flanges, or built-up segmental girders	0.009	0.006
For collar friction at ends of conical rollers	0.15	0.10
For bending of wire ropes, for each sheave, the coefficient of direct tension in rope	$\frac{d^2}{3D}$	$\frac{d^2}{3D}$
(d = diam. of rope in inches, D = diam. of sheave in inches.)		
For rolling friction of solid cast rollers without flanges:		
(a) In contact with one surface only	$\frac{3}{200r}$	$\frac{3}{200r}$
(b) In contact with two surfaces	$\frac{3}{100r}$	$\frac{3}{100r}$
(r = the radius of the roller in inches.)		

In designing the machinery for holding the span against the 15 lb. wind pressure specified, and for computing braking effect, 0.4 of the above mentioned coefficients for motion shall be used. Rope stiffness, solid roller friction, and machinery friction shall be disregarded.

For sliding friction between plane surfaces intermittently lubricated (such as guides on tower posts), the coefficient of friction shall be taken as 0.08.

Machinery Losses

310. In computing the machinery losses between the operating rack, or the operating rope, or a similar point, and the prime mover, the following coefficients shall be used:

For journal friction	0.05
For efficiency of any pair of gears, journal friction not included:	
Spur gears	0.98
Bevel gears, collar friction included	0.90
Efficiency of worm gearing, angle of thread 20 degrees or more, collar friction included	0.60

Brakes

311. The machinery, including the brake mechanism, shall be capable of resisting the stresses caused by stopping the bridge in five seconds. The braking capacity shall be sufficient to stop the bridge in ten seconds. The coefficient of friction for braking shall be taken at 0.25. If practicable, the pressure per square inch on the rubbing surface of the brake shall not exceed 25 lb.

If brakes act through the machinery, the unit stresses produced in the machinery by braking shall not exceed 1½ times those allowed for the normal torque of the prime mover. However, for the braking mechanism and for parts which receive stress only through braking, the unit stresses shall not be increased.

Unit Stresses

312. Structural parts shall be proportioned by the current Specifications for Steel Railway Bridges of the American Railway Engineering Association.

The following unit stresses in pounds per square inch shall be used for machinery and similar parts in which main stresses are not increased by impact:

Material	*Tension*	*Compression*	*Fixed Bearing*	*Shear*
Rolled or forged steel	9,000	9,000 — 40 l/r	13,000	6,500
Stress in extreme fibers of trunnions	13,000	13,000		
Cast steel	7,000	8,000 — 35 l/r	10,000	5,000
Phosphor-bronze	6,000	6,000		4,500
Cast iron	1,500	8,000*	8,000	2,000
Keys			9,000	5,000

*For struts whose l/r is 20 or less.

For stresses which are reversed at the rate of ten or more times a minute, two-thirds of the above mentioned unit stresses shall be used.

Bearing Pressures

313. The following maximum bearing pressures, in pounds per square inch, for rotating and sliding surfaces shall be used:

(a) For intermittent motion with speed not exceeding 100 ft. per minute:

Pivots of swing bridges, hardened tool steel on phosphor-bronze discs	3,000
Trunnion bearings, structural steel on phosphor-bronze	1,500
Wedges, cast steel on cast steel or structural steel	500
Screws which transmit motion (on projected area of thread)	200

(b) For speeds exceeding 100 ft. per minute:

Hardened steel on hardened steel	2,000
Hardened steel on bronze	1,500
Structural steel on bronze	600
Structural steel on babbitt metal or brass	400
Structural steel on cast iron	400
Cross-head slides (speed not exceeding 600 ft. per minute)	50

Journal and Pivot Bearings

314. The pressure on pivots or step bearings for vertical shafts, and on journals, shall not exceed:

On pivots, $p = \dfrac{60,000}{nd}$, but not more than 900.

On journals, $p = \dfrac{250,000}{nd}$, but not more than 600.

On collars, $p = \dfrac{50,000}{nd}$, but not more than 200.

p = pressure in pounds per square inch.
n = number of revolutions per minute.
d = diameter of pivot or journal or mean diameter of collar in inches.

For crank pins and similar joints with alternating application and release of pressure, the bearing values given by the foregoing formulas may be doubled.

Pressure on Rollers

315. The permissible pressure in pounds a linear inch of rollers shall be:

For rollers in motion: (d not to exceed 64 in.)	
Cast iron	$200d$
Cast steel	$400d$
Structural steel	$300d$
Tool steel	$800d$
Hardened tool steel	$1000d$
For rollers at rest: (d not to exceed 28 in.)	
Rolled or cast steel	$600d$
(d = diameter of roller in inches.)	

The foregoing values are for rollers and bearing surfaces of like materials. If the rollers and bearing surfaces are of unlike materials, the lower value shall be used.

Wire Ropes

316. The total unit tension in counterweight ropes shall not exceed one-fifth of the specified unit ultimate strength of the rope, nor shall the unit tension from the direct load only exceed one-tenth of the specified unit ultimate strength. For operating ropes, the corresponding limits shall be one-third and one-sixth.

317. If a wire rope is bent over a sheave, the bending stress and permissible load on the rope shall be calculated as follows:

Let $P =$ the permissible load on rope, in pounds.
$K =$ unit stress due to bending in extreme fiber of largest individual wire.
$E =$ modulus of elasticity $= 28{,}500{,}000$.
$a =$ cross-sectional area of rope in square inches.
$d =$ diameter of largest wire in inches.
$D =$ diameter of sheave, center to center of rope, in inches.
$S =$ greatest unit tension allowable.
$L =$ angle of helical wire with axis of strand.
$B =$ angle of helical strand with axis of rope.
$c =$ diameter of rope.

$$\text{Then } K = \frac{Ed\cos^2 L\cos^2 B}{D} \quad \text{.......... (1)}$$

$$P = a\left[S - \frac{Ed\cos^2 L\cos^2 B}{D}\right] = a\left[S - \frac{0.9Ed}{D}\right] \quad \text{.......... (2)}$$

For rope having 6 strands of 19 equal wires each,

$$P = a\left[S - \frac{1700000c}{D}\right] \quad \text{.......... (3)}$$

assuming $d = \dfrac{c}{15}$.

For haulage rope, 6 strands of 7 wires each, $d = \dfrac{c}{9}$.

318. If a rope is in contact with a small sheave over a short arc (50 degrees or less), the actual radius of curvature of the rope may be greater than that of the sheave.

Let $R =$ the actual radius of curvature of the rope.
$\theta =$ the angle between the directions of the rope.
$W =$ pull on individual wire (equals P divided by the number of wires if all wires are of equal diameters).

$$\text{Then } R = \frac{d^2}{4.25\cos\frac{\theta}{2}}\sqrt{\frac{E}{W}}$$

If R is greater than the radius of the sheave, $2R$ should be used in place of D in formulas (1), (2) and (3).

Shafts

319. Circular shafts, trunnions and axles shall be proportioned by the following formulas:

$$f = \frac{32}{\pi d^3}\left[\frac{3}{8}M + \frac{5}{8}\sqrt{M^2 + T^2}\right]$$

$$S = \frac{16}{\pi d^3}\sqrt{M^2 + T^2}$$

$f =$ unit extreme fiber stress in tension or compression.
$S =$ unit shear.
$d =$ diameter of shaft at the section considered.
$M =$ simple bending moment computed for the distance center to center of bearings.
$T =$ simple twisting moment.

In the case of reversal at the rate of ten or more times a minute, increase *M* one-half. In this case, *f* shall not be reduced on account of reversal.

If a shaft, trunnion, or axle has one keyway at the section where the maximum stresses occur, *f* and *S* shall be considered to be increased by one-sixth; if two keyways, by one-fourth.

Excess Loads

320. The machinery parts shall be designed for the loads specified in Article 308, using the unit stresses herein given. For the stresses caused by the motor when exerting twice the greatest normal torque, twice the normal unit stresses may be used.

End Lift Machinery

321. In designing the machinery parts for the end lifts of swing bridges, the same methods specified for the machinery actuating the moving span shall be used.

Impact

322. Impact in trunnions, wire ropes, wire rope attachments, and machinery parts is allowed for in the foregoing unit stresses.

(IV) DETAILS OF DESIGN

Rail End Connections

401. Designs for rail end connections will be furnished by the Engineer. If the connections are of the sliding rail lock type, the ends of the bridge rails shall be fixed, cut square, and connected with the approach rails by sliding sleeves or joint bars, to carry the wheels over the openings between the rail ends. The distance from the center of the track to the inside of the rail lock wheel tread shall be not less than 2 feet 6 inches, and not more than 2 feet 6½ inches, the heads of the rails being planed off on the outside if necessary. At the heel end of bascule bridges, the sliding locks shall be on the approach. Sliding rail locks, if power operated, shall have not less than 2½ horsepower per track for each end of the bridge (but not less than 5 horsepower at each end of the bridge).

Rim Girders

402. Rim girders shall be provided with stiffeners with fillers on both sides of the web at points of concentrated loading. These stiffeners shall fit close against both flanges. The distance between adjacent intermediate stiffeners shall not exceed two feet. On rim girders exceeding five feet in depth, alternate intermediate stiffeners may extend only half the depth of the girder, unless required to be of full depth to stiffen the web. The thickness of the outstanding legs of stiffener angles shall be not less than one-eighth of their width. The tread plate for the rollers shall be securely fastened to the rim girder and shall be from 2 to 3 inches thick, depending on the weight of the bridge. The rim girder flange angles shall be not smaller than 6 inches by 4 inches by ¾ inch.

Centering and Locking Devices

403. Bascule and vertical lift bridges shall be provided with self-centering and seating devices at the free end. There shall be a locking device for each truss to force down and hold the free end.

Air Buffers

404. Power operated skew swing bridges and all bascule and vertical lift bridges shall be provided with air buffers; for single track bridges, one at the free end of bascules, and one at each end of vertical lifts. For multiple track bridges, twice the number shall be used. The inside diameter of the cylinder shall be not less than 12 inches, and the travel of the piston not less than 24 inches. There shall be three cast iron packing rings for each piston.

End Lift and Center Wedges

405. The end lifting apparatus of swing bridges shall be arranged to center the bridge accurately when closed unless a separate device is used to center the bridge. The end lift and center wedges shall be so designed that the action of the moving load cannot cause displacement of the end supports and wedges in case of failure or disconnection of the mechanism which actuates the end lift. The end lifting apparatus and center wedges shall be so designed as to permit adjustment. The center and end wedges may be operated by the same mechanism.

Counterweights

406. Counterweights usually shall be of concrete supported by a steel frame. The concrete may be inclosed in a steel box. Counterweights shall be so made as to be adjusted easily for variations in the weight of the moving span. Usually this shall be done by adding or taking off properly located cast iron or concrete blocks. Space for 3½ per cent under and 5 per cent above the calculated weight shall be provided. Movable blocks to the amount of 3½ per cent shall be provided.

In vertical lift bridges the counterweights shall clear the track rails by not less than 3 feet when the span is fully opened. The counterweight ropes shall be assumed to stretch two per cent. of their figured length.

407. In vertical lift bridges, counterweights hung by ropes shall be divided into parts so that each part will be hung by not more than sixteen ropes. The ropes of each group shall be attached to the part by an equalizer.

Pockets in Counterweights

408. Pockets in counterweights shall be provided with drain holes not less than six inches in diameter. The pockets shall be covered. The cover, its fastenings and frame shall be metal.

Concrete

409. Concrete, unless otherwise specified, shall be composed of 1 part of Portland cement, 2½ parts of sand and 5 parts of stone. Otherwise the concrete shall conform to the specifications of the Company. In counterweights, steel punchings or scrap metal may be used to increase the weight. The punchings or metal shall be placed in layers and grouted with motar composed of 1 part of cement and 2 parts of sand; the maximum available

weight shall not exceed 315 pounds a cubic foot. If the counterweight containing such mixture of metal or punchings revolves about a horizontal axis, it shall be retained in place by a surrounding steel box, or by walls of concrete.

Concrete counterweights of the revolving type shall be poured continuously if practicable.

For ascertaining the weight of the concrete, test blocks having a volume of one cubic foot shall be cast at least thirty days before concreting is begun. The consistency of the concrete in the test blocks shall be the same as that of the concrete in the counterweight.

Diameter of Sheaves

410. For counterweight ropes, the diameter of the sheave (measured from center to center of ropes) shall be not less than 75 times the diameter of the rope; 90 times is preferable. For operating ropes, the diameter of the drum shall be not less than 45 times the diameter of the rope; 50 times is preferable.

Disc Bearings

411. Center bearing bridges shall revolve on disc bearings. Disc bearings shall consist of two discs, one of phosphor-bronze and one of hardened steel.

Center Pivots

412. Center pivots shall be so designed that the discs may be taken out and replaced while the bridge is closed, without interfering with the operation of trains over the bridge. The discs shall be so anchored that sliding will take place only at the surfaces of contact of the discs.

Balance Wheels

413. For power operated center bearing bridges, no fewer than eight wheels, running on a circular track, shall be provided to limit the tilting of the bridge and to carry the wind pressure to the track while the bridge is swinging. The balance wheel bearings shall be adjustable for height, preferably by shims between the superstructure and the seats of the bearings. For short, single track, hand operated bridges, four wheels may be used.

Wheels shall be fastened to the trunnions by keys.

Rack and Track

414. The rack and track of swing bridges shall be made in sections, preferably not less than 6 feet long. The track shall be deep enough to insure good distribution of the balance wheel or roller loads to the masonry, but in no case shall the depth for rim-bearing bridges be less than four inches. If a cast track is used and the loads are light, as in center-bearing bridges, the rack and track segments preferably shall be cast in one piece. In rim-bearing bridges, the rack shall be cast separate from the track, so that the parts may be easily removed for repairs. The joints in the rack and track shall be staggered. The track shall be anchored to the masonry by bolts not less than 1½ inches in diameter, extending at

least 12 inches into the masonry, and set in Portland cement mortar or grout. The track of hand operated center-bearing bridges shall have an ample number of anchor bolts so that the mortar or grout in which they are set will not be crushed by the tractive force developed when turning the bridge. When center-bearing bridges are operated by mechanical power, the track shall be anchored down by bolts and the tractive force developed when turning the bridge shall be taken by lugs extending from the bottom of the track downward into the masonry and set in cement mortar, grout or concrete.

Segmental Girders and Track Girders

415. The flanges of the segmental girders and the track girders of rolling bridges shall be symmetrical about the central planes of the webs. The central planes of the webs of the segmental girders shall coincide with the corresponding central planes of the webs of the track girders. That part of the outstanding leg of a flange angle which is beyond the outside face of the vertical leg shall not be considered as bearing area. The width of contact between the segmental girder and the back of the tread plates shall be equal to the corresponding width of contact in the track girder.

Rollers and wheels with full circumference shall be rolled, forged or cast in one solid piece.

The treads attached to the segmental girders and the track girders shall be steel castings and shall not be considered as part of the flange of these girders. There shall be open joints between adjacent castings. For any position of the bridge the treads shall be considered as pedestals distributing the line bearing pressure between them to the girders. To effect this distribution properly, the castings shall be proportioned as to depth, width and unit stresses as a cast base under a column.

The permissible load in pounds a linear inch of line bearing between treads shall be $3200 \sqrt{d}$ (d being the diameter of the roller in inches). The bearing of metal on metal, considering the area covered by planes 45 degrees from the perpendicular from point of contact, shall not exceed 13,000 lb. a square inch. The material in the tread castings at the joints shall fulfill the above requirements. The surfaces of contact between the segmental girder and the tread castings preferably shall be plane surfaces. The loads considered in this paragraph shall include 20 per cent impact as provided in Article 302.

Machinery Design

416. The machinery shall be simple and substantial in design, and easily erected, inspected, adjusted, and taken apart. The fastenings shall be adequate to hold the parts in place under all conditions of service. If practicable, the machinery shall be mounted on a self-contained cast steel frame or base; otherwise on a rigid structural steel support.

Location of Machinery

417. The location of the machinery shall be such as to allow easy access and room for ample size of supporting parts. In bascule bridges, the machinery preferably shall be on the stationary part.

Bearings

418. Bearings shall be placed close to the points of loading. The bearings for mating bevel gears shall be made in one solid piece. The length of a bearing shall be not less than the diameter of the journal.

419. Journal bearings shall be of the divided type. The cap shall be recessed into the base and fastened by turned bolts recessed into the base. Cap screws for this fastening will not be accepted. Nuts shall be hexagonal. Check nuts shall be provided. The holes in the supports shall be ¼ inch smaller than the bolt, for subsequent reaming. The nuts of bolts shall bear on finished bosses or spot faced seats. The bearings shall be designed to facilitate cleaning. Trunnion bearings shall have outlets for flushing.

420. Provision shall be made for alining shafts that cannot be fitted in the shop.

421. In swing bridges, the main pinion shaft bearings shall be designed with enough shims to provide for overrun or underrun in the diameter of the rack as fitted up in the shop, and, if feasible, the bearings shall be shipped with the necessary shims in position. Provision shall be made for adjustment for wear and in height of all important bearings, and adjustment of their caps, by means of liners or some other effective device, where it is obvious that such adjustment will be necessary.

Linings

422. Bearings for main pinion shafts and for shafts carrying heavy loads shall have phosphor-bronze linings; for other cast steel bearings, the lining may be of bronze or babbitt metal. The lining shall be provided with an effective device to prevent it from rotating. The force tending to cause rotation shall be taken as one-sixth of the load on the trunnion or bearing and as acting at the outer circumference of the lining. There shall be ⅛ inch clearance between the lining of the cap and the lining of the base. The inside longitudinal corners of the lining shall be rounded except for a distance of ⅜ inch from each end. Cast iron bearings need not be lined.

Main Pinion Shaft Bearings

423. When the tooth load on the rack requires difficult connections of the rack to the masonry, two or more pinions shall be used. When two pinions are used, they shall be placed diametrically opposite. When four pinions are used, they shall be placed in pairs diametrically opposite.

The brackets that support the rack pinions shall be of ample strength for the maximum pinion force. They shall be in a single piece supporting both bearings of the pinion shaft. They shall be thoroughly braced and rigidly attached to the rim girder or the superstructure.

The pinion shaft bearings preferably shall be cast in one piece. The bearings shall be provided with caps so that the pinion shaft can be taken out without removing the bearings or the bracket.

Means shall be provided for holding the pinions against movement along the shaft.

Lubrication

424. Provision shall be made for effective lubrication of sliding surfaces. Lubricating devices shall be easily accessible.

Screw compression tell-tale grease cups shall be provided for journal bearings. If the journals are not accessible, the cups shall be connected by pipes. Grease ducts shall be so located that the lubricant will tend to flow by gravity toward the bearing surface. Grooves shall be provided wherever necessary for the proper distribution of the lubricant.

The grooves for large trunnion bearings shall be cut in the trunnion. They shall be straight, parallel with the axis of the trunnions, and no fewer than three. They shall be so located that the entire bearing surface of the lining will be swept by the lubricant in one movement of opening or closing the bridge. The bottom of the groove shall be rounded. The corners shall be rounded to a ¼-inch radius. The size shall be such that a $\frac{5}{16}$-inch wire will lie wholly within the groove. The grooves shall be accessible for cleaning with a wire.

In disc bearings straight grooves shall be cut in the upper one of the two rubbing surfaces in contact. The grooves shall be not less than one-fourth inch in width and depth and the corners shall be rounded to a radius not less than half the width of the groove. The corners at the bottom of the grooves shall be filleted; there shall be no sharp corners.

Covers

425. Dust covers shall be provided wherever necessary to protect the sliding and rotating surfaces and prevent dust from mixing with the lubricant.

If gears or sheaves are located where falling objects may foul them, they shall be protected by metal covers easily removed.

Counterweight sheave rims shall be covered to protect them from the weather.

Shafts

426. For shafts supporting their own weight only, the unsupported length of the shaft shall not exceed $L = 80 \sqrt[3]{d^2}$ in which: L = length of shaft between bearings in inches; d = diameter of shaft in inches.

Line shafts connecting the machinery at the center of the bridge with that at the ends shall be designed to run at fairly high speed, the speed reduction being made in the machinery at the end.

Shafts transmitting power for the operation of the bridge, and shafts four feet or more in length forming part of the operating machinery of rail locks and bridge locks, shall be not less than 2½ inches in diameter.

Journals on cold rolled shafting shall not be turned down.

Mechanical devices using power transmitted by compressed air may be used for the operation of center wedges, end lifts, centering devices and sliding rail locks.

Collars

427. Collars shall be provided wherever necessary to prevent the shaft from moving lengthwise. There shall be at least two set screws, 120

degrees apart in each collar. If a shaft or trunnion receives a longitudinal force, there shall be a thrust bearing to prevent longitudinal movement.

Longitudinal Thrust

428. Wheels and similar parts shall be securely fastened, to prevent longitudinal movement, by set screws through the hub or by clamps around the shaft. The hubs of bevel gears shall bear against the shaft bearing. Provision shall be made to hold bevel gears and worm wheels against movement along the shaft.

Step Bearings

429. The bearing ends of vertical shafts running in step bearings shall be of tool steel, and shall bear on bronze discs.

Shaft Couplings

430. Shafting liable to be thrown out of line by the deflection of the supporting structure shall be made in non-continuous lengths connected by claw couplings. These couplings shall be fitted together accurately, but with allowance for a slight angular motion without bending the shaft. Each length of shafting of this kind preferably shall rest in not more than two bearings. The couplings shall be close to the bearings.

Couplings in shafting other than the above mentioned shall be of the flanged or the split muff type. The bolt heads and nuts shall be seated in recesses, or protected by flanges. The couplings shall be cylindrical. They shall be keyed to the shaft.

Gear Teeth

431. Gear teeth shall be of the involute type. The angle of obliquity shall be 20 degrees. The radial height of the tooth above the pitch line shall not exceed 0.32 of the circular pitch.

The width of face of a spur gear tooth shall be not less than 1½ times the circular pitch. For pitch circle speeds not exceeding 600 feet a minute, the width shall be not more than three times the circular pitch. The width of face of a bevel gear tooth shall not exceed one-third of the slant height of the pitch cone, or three times the pitch at the middle section.

The circular pitch of gear wheels (other than motor pinions) transmitting power for moving the span shall be not less than 1¼ inches. For the pinion engaging the operating rack, the pitch shall be not less than two inches.

No pinion shall have fewer than twelve teeth and where feasible fifteen. No pinion with stub teeth shall have fewer than fourteen.

Strength of Gear Teeth

432. In spur gears and bevel gears, the load transmitted shall be taken as applied on one tooth only; in worm wheels, as being equally distributed between two teeth.

A standard shaped tooth is one having the following characteristics: (a) The profile is a 20 degree involute curve; (b) the radial height outside of the pitch circle is closely 0.32 of the circular pitch; (c) the thickness of the tooth at the pitch circle is half of the circular pitch.

The allowable load on cut gear teeth of standard shape shall conform to the following formula:

$$W = psf\left(0.154 - \frac{0.912}{n}\right)\frac{600}{600 + V}$$

W = the allowable load on the tooth in pounds.
s = the permissible stress in pounds a square inch:
= 9,000 for bronze.
= 16,000 for steel.
f = width of face of tooth in inches.
p = circular pitch in inches.
V = velocity of pitch circle in feet a minute.
n = the number of teeth in the gear.

The allowable load on machine molded teeth shall conform to the foregoing formula, taking $s = 14{,}000$ for cast steel.

For teeth not of standard shape, the following formula shall be used:

$$W = \frac{sft^2}{6r} \times \frac{600}{600 + V}$$

t = thickness of tooth in inches at section under consideration.
r = radial height of tooth in inches measured from section where t is taken.

The other symbols are defined as in the formula for standard teeth.

For calculating the teeth of bevel gears, the middle section of the tooth shall be taken.

Teeth to Be Cut

433. The teeth of gears transmitting power for the operation of the bridge, bevel gears, and wheels in the gearing of any motor, shall be machine cut.

Equalizing Devices

434. In power operated swing bridges there shall be no fewer than two rack pinions. The shafts of these pinions shall be connected by a device which will equalize the turning forces at the pinions.

There shall be devices on bascule and vertical lift bridges to equalize the forces at the pinions.

Worm and Screw Gearing and Cams

435. In worm gearing and screw gearing for transmitting power (except for end lifts of swing bridges), the angle of the thread shall be not less than 20 degrees. For end lifts and wedges, the angle of the thread shall be small enough to prevent reverse motion under load. The worm shall run in oil. There shall be bronze collars at the ends of the screw in screw gearing, and on the worm wheel axle in worm gearing, to take the end thrusts. The wheel in worm gearing and the nut in screw gearing shall be of bronze. Screws shall have square threads. Worm wheels shall have no fewer than 30 teeth. Worm and wheel gearing shall be enclosed in a cast iron casing. The worm shall be below the wheel.

Except for end lifts of swing bridges, worm and screw gearing preferably shall not be used for transmitting power.

Cams and similar devices transmitting power by line or point contact shall not be used.

Springs

436. Springs preferably shall not be used to actuate any moving part. For electrical parts, preference will be given to those having the fewest springs.

Keys and Keyways

437. Keys for fastening machinery parts to shafts shall be gib head keys, tapered if practicable; if not practicable, parallel faced. The keys shall be sunk in keyways in both hub and shaft.

The taper of the key shall be ⅛ inch per foot. The width shall be one-fourth of the diameter of the shaft. The height at the middle of the tapered length shall be three-fourths of the width. The length of the gib head, measured parallel with the shaft, shall be equal to the width of the key. The foregoing dimensions are approximate; the shape of the key and the depth of the keyway shall be such that the allowed unit stresses in shear and bearing will not be exceeded.

The length of the tapered part of the key shall be not less than that of the hub plus one-fourth of the diameter of the shaft.

If two keys are provided, they shall be placed 120 degrees apart.

If practicable, the keyway in the shaft shall be made long enough to allow the key to be inserted without moving the hub along the shaft and long enough to extend beyond the point of the key, after the key is firmly seated, a distance not less than three-eighths of the diameter of the shaft. The clear distance between hub and head of key shall be not less than one-fourth of the diameter of the shaft.

Capacity of Keys

438. The foregoing requirements for keys and keyways are for machinery parts whose use is intended to develop the full torsional strength of the shaft. For minor parts, the keys and keyways shall be proportioned for that size of shaft whose torsional strength would be developed by such parts.

For trunnions and similar parts which are designed chiefly for bending and bearing, the keys and keyways shall be proportioned simply to hold the trunnion from rotating. The force tending to cause rotation shall be taken as one-fifth of the load on the trunnion, and as acting at the circumference of the trunnion.

Fastening Keys

439. Keys shall be held by safety set screws or other effective means. In vertical shafts, bands clamped about the shaft, or other devices, shall be placed below the key.

If practicable, the keys and keyways shall be so made that the keys may be backed out.

Hubs

440. If practicable, the length of the hub shall be not less than 1¼ times the width of the teeth and preferably not less than the diameter of the bore; the thickness not less than two-fifths of the diameter of the bore.

The fit of the hub on the shaft shall be obtained by observing the following variations from the nominal diameter in inches.

Nominal Diameter Inches	Diameter of Hole, Inches		Diameter of Shaft, Inches	
	Maximum	Minimum	Maximum	Minimum
1	1	0.998	0.999	0.998
2	2	1.998	1.999	1.998
3	3	2.998	2.999	2.998
4	4	3.997	3.998	3.997
5	5	4.997	4.998	4.997
6	6	5.997	5.998	5.997
7	7	6.996	6.997	6.996
8	8	7.996	7.997	7.996
9	9	8.996	8.997	8.996
10	10	9.996	9.997	9.996

Counterweight sheaves of vertical lift bridges, and main pinions, shall have pressed fits with keys.

The keyway in the hub shall be on the center line of an arm.

Bolts and Nuts

441. Bolt heads and nuts shall bear on seats at right angles to the bolts. On castings, except where recessed, the bearing shall be on finished bosses or spot faced seats. Bolt heads which are recessed in castings shall be square.

Nuts which are subject to vibration and frequent changes of load shall be secured by effective locks. If double nuts are used, both nuts shall be of standard thickness.

Set Screws

442. Set screws shall not be used for transmitting torsion; they may be used for holding keys or light parts in place.

Tap Bolts and Stud Bolts

443. Tap bolts and stud bolts shall not be used except by special permission of the Engineer.

Operating Ropes

444. For operating ropes, there shall be at least two full turns of the rope on the drum when the span is in the fully open or fully closed position. If practicable, the number of turns shall be sufficient to develop the ultimate strength of the rope by friction, the coefficient of friction being taken as 0.20. The rope shall be so attached to the drum as to avoid sharp bends in the wires. There shall be a turnbuckle or other device for taking up slack in the rope.

Counterweight Ropes

445. The deviation of counterweight ropes from the vertical shall be as small as practicable. The deviation from the plane through the center of the groove shall not exceed 1 in 40.

Rope connections shall be so made that any rope may be renewed without disturbing the other ropes.

Safety Guards

446. Safety guards for the protection of persons shall be installed. All safety regulations shall be observed.

Built Sheaves

447. In built sheaves, there shall be enough rivets connecting the flanges of the cast rim with the web to carry into the web all of the load coming on the rim. The rim shall be strengthened by transverse ribs, or shall be thick enough to carry the load.

Drain Holes

448. At places where water is likely to collect, there shall be drain holes not less than one inch in diameter.

Equalizing Levers

449. The net section back of the pin hole in equalizing levers shall be equal to the net section which would be required in tension to carry the load on the pin.

(V) WIRE ROPES AND ATTACHMENTS

Manufacturer

501. Wire rope shall be made by a manufacturer whose facilities and reputation are approved by the Engineer.

Laying

502. Ropes shall be laid in accordance with the best practice, in an approved lubricant.

Splices

503. Ropes shall not be spliced.

Wires—Size and Number

504. The diameter of counterweight ropes shall be not less than one inch, nor more than two and one-half inches; of operating ropes not less than three-fourths of an inch.

The ropes shall be made of improved plow steel and shall consist of six strands of 19 wires each laid around a hemp center.

Sockets

505. Sockets shall be forged without welds from solid steel. The dimensions of sockets shall be such that no part under tension will be stressed higher than 65,000 lb. per square inch when the rope is stressed to its specified ultimate strength. The sockets shall be attached to the rope by a method which is reliable and which will not permit the rope to slip in its attachment to the socket.

Wire—Physical Properties

506. The wire from which counterweight ropes are made shall be tested in the presence of an inspector designated by the Engineer. It shall show the following physical properties:

(a) A tensile strength of not less than 225,000 lb. a square inch.

(b) A total elongation (measured on a piece 12 inches long) of not less than 2.4 per cent.

(c) The number of times a piece six inches long can be twisted around its longitudinal axis without rupture shall be not less than 1.4 divided by the diameter in inches.

(d) The number of times the wire can be bent 90 degrees alternately in opposite directions over a jaw the radius of which is equal to twice the diameter of the wire, without fracture, shall be not less than six. This test shall be made in a mechanical bender so constructed that the wire actually conforms to the radius of the jaws and is subjected to little tensile stress.

Ultimate Strength

507. In order to test the strength of the rope and fastenings, a number of test pieces not more than twelve feet long, with sockets (selected at random from those which are to be used in filling the order) attached to each end, shall be stressed to destruction in a suitable testing machine. The number of test pieces shall be not more than ten per cent of the total number of finished lengths of rope to be made, nor less than two from each original length. Under this test, the rope shall develop the ultimate strength given in the table below:

ULTIMATE STRENGTH OF 6x19 IMPROVED PLOW STEEL ROPE

Diameter of Rope in Inches	Area of Section $0.4D^2$	Ultimate Strength Pounds	
		Per Sq. Inch	Entire Rope
½	0.100	210,000	21,000
⅝	0.156	208,000	32,000
¾	0.225	206,000	46,000
⅞	0.306	204,000	63,000
1	0.400	202,000	81,000
1⅛	0.506	200,000	101,000
1¼	0.625	198,000	124,000
1⅜	0.756	196,000	148,000
1½	0.900	194,000	175,000
1⅝	1.056	192,000	202,000
1¾	1.225	190,000	233,000
1⅞	1.406	188,000	264,000
2	1.600	186,000	298,000
2¼	2.025	184,000	373,000
2½	2.500	182,000	455,000

Rejection

508. If the physical qualities of the rope or of its individual wires fall below those specified, the entire length from which the test pieces were taken shall be replaced by the manufacturer with a new length, the physical qualities of which conform to those specified.

Testing Sockets

509. If slipping in the sockets should occur during the test, the method of fastening the sockets shall be changed until slipping does not occur. The sockets shall be stronger than the rope to which they are attached. If a socket should break during the test, two others shall be selected and attached to another piece of rope and the test repeated. This process shall be continued until the Inspector is satisfied as to the reliability of the sockets. If the Inspector is satisfied, the lot shall be accepted. If, however, 10 per cent or more of the sockets tested break at a load less than the specified minimum ultimate strength of the rope, the lot shall be rejected.

Facilities for Testing

510. The manufacturer shall provide proper facilities for making the tests, and shall make, at his own expense, the tests required. Tests shall be made in the presence of an Inspector representing the Engineer.

Length

511. The length of each rope shall be measured while the rope is supported throughout its length in a straight line and under a tension of 2 per cent of its ultimate strength. A variation from the required length of not more than one-quarter of an inch in 100 feet, will be allowed.

Coils

512. Ropes shall be shipped on reels of a diameter not less than thirty times that of the rope.

Equalizing Levers

513. The equalizing levers, and their pins more than seven inches in diameter, shall be of forged steel. Pins seven inches or less in diameter shall be of either rolled steel or forged steel.

(VI) POWER EQUIPMENT

(a) General Requirements

Kind of Power

601. If the bridge is to be operated by mechanical power, the kind of power to be used will be stipulated by the Company. The motors shall be of ample capacity to move the bridge at the required speed. The type of the motor and the name of the manufacturer shall be given in the bid. The term motor, as used in these specifications, means the prime mover whether steam, internal combustion, or electric.

Man Power

602. If the bridge is to be operated by hand, the number of men and the time required to operate it shall be calculated on the assumption that the force one man can exert continuously is 40 lb. at a speed of 160 ft. per minute, developing about one-fifth H.P. For calculating the strength of the machinery parts, the force of one man shall be assumed as 125 lb., and the force applied to the extreme end of a hand lever shall be assumed as 150 lb.

Machines

603. Machines which are of the usual manufactured types, such as steam, gasoline, and electric motors and pumps, air compressors, etc., shall be tested for the specified requirements to the satisfaction of the Engineer, and shall be guaranteed by the Contractor to fulfill these requirements for one year.

Torque of Motors

604. The motors shall be capable of exerting, through successive cycles of bridge operation extending through 30 minutes, the torques shown on the torque curves for the loads specified in Art. 308; and for 15 minutes, twice those torques. A cycle is defined as an opening and a closing of the bridge without a period of rest between closing and opening, and without a change of wind in amount or direction. Successive cycles shall be taken without periods of rest.

Electrical Control

605. The electrical control shall be manual, remote, or automatic. The kind will be stipulated by the Company.

Brakes

606. Electrically operated vertical lift bridges shall be provided with a solenoid brake for each main motor, and in addition a motor operated service brake with three steps of retarding torque. If stipulated, the service brake shall be operated by air, or by hand.

Electrically operated bascule bridges and swing bridges shall be provided with a solenoid brake for each main motor, and in addition with an emergency brake which shall be located as close to the operating rack as practicable.

Brakes for bridges operated by power other than electricity shall be operated by air, by hand, or by foot.

Whistle or Horn

607. A whistle or an electric horn shall be installed complete.

The horn shall be audible at a distance of 1,500 feet under the conditions surrounding the site and with the wind blowing in any direction.

The bell of the whistle shall be not less than 3 inches in diameter and 9 inches long. If the whistle is operated by air, the compressor shall be power driven, the motor and compressor being gear connected on one frame. The working parts shall be enclosed and self-lubricating. The compressor shall have a piston displacement of from 25 to 30 cubic feet a minute when working against a tank pressure of 90 lb. a square inch. The compressor shall be provided with an automatic governor and switch in order that the compressor may start and stop automatically at any predetermined tank pressure.

The air receiving tank shall be 36 inches in diameter and 8 feet long, or of equal capacity. It shall be good for a working pressure of 125 lb. a square inch. It shall be provided with pressure gage, pop valve, and drain cock, and shall have standard flanges bushed for 1½-inch pipe. The Contractor shall furnish and install pipe, pipe fittings and valves; all to withstand a working pressure of 125 lb. a square inch.

(b) Steam

Steam Engines

608. Steam engines shall be of the double-cylinder, reversing type, and shall develop the required power at a piston speed not exceeding 500 feet per minute with a steam pressure of 75 lb. per square inch at the throttle. The engine shall be connected to the operating machinery by an approved friction clutch, so arranged that the moving machinery and the locking machinery may be operated independently or stopped without stopping the engine.

Steam Separator

609. There shall be a steam separator in the steam supply pipe close to the steam chest. This separator, under test with quality of steam as low as 66 per cent, shall show an average efficiency of 85 per cent in five tests.

Boilers

610. There shall be installed one or two boilers as stipulated. The boilers shall be upright tubular boilers with submerged tubes. They shall be designed for a steam pressure of 150 lb. per square inch, and shall be adapted to the kind of fuel specified by the Engineer. Boilers shall be in accordance with the Code of the American Society of Mechanical Engineers, adopted February, 1915, with additions and revisions, and shall conform to civil regulations. They shall be encased in asbestos covered with planished iron.

Boiler stacks and breechings shall be made of ingot iron not less than $\frac{3}{16}$-inch thick. They shall be of ample diameter and height to furnish the required draft under the conditions at the site. There shall be a damper in the stack.

Horsepower of Boilers

611. The capacity or boiler horsepower of each boiler shall be such as to furnish at least twice the quantity of steam required by the engine when it is working at the specified steam consumption rate for the brake horsepower required. At least 15 square feet of heating surface and one-third square foot of grate surface shall be allowed for each boiler horsepower.

Pipes and Coverings

612. Steam pipes and fittings shall be extra heavy and shall be covered with 85 per cent magnesia sectional covering jacketed in canvas. Water pipes shall be protected from freezing, if necessary.

Engine Room Appliances

613. In the engine room, there shall be a steel water tank of sufficient capacity, a duplex steam boiler feed pump, and an injector for each boiler, with necessary pipes and connections for feeding boilers separately or together. Steam water lifters with necessary strainers, flexible hose, and piping to lift the water from the river into the tank shall be provided if the river water is fit for boiler use. A coal hoist and a steel coal bin of sufficient capacity shall be provided. There shall be in the engine room

indicators to show the position of the moving span and of the lifting and locking apparatus.

(c) Internal Combustion

Gasoline Engines

614. Gasoline and other internal combustion engines shall be of the automobile or the marine type and of the most substantial kind. The piston speed shall not exceed 1,600 feet a minute. The engine shall be equipped with a reversing gear with approved friction clutches, to be operated by a hand wheel or lever. The countershaft connecting the engine with the operating machinery shall be provided with disengaging couplings so arranged that the moving machinery and the end lifting or end locking machinery may be operated independently and in either direction without stopping the engine. Engines of 20 H.P. or more shall be equipped with a starting device actuated by an electric motor or by compressed air. A tank of sufficient capacity for cooling water, or a radiator and fan, shall be installed in the engine room. The fuel tank shall be located outside the engine room, below the level of the cylinder. The tank shall be large enough to hold fuel for 30 days of normal operation. It shall be protected from the sun.

There shall be in the engine room indicators to show the positions of the moving span and of the lifting and locking apparatus.

Ignition

615. If the fuel is suitable (such as gasoline and kerosene) the ignition shall be of the jump-spark kind, for which the secondary coil is made up so that a low voltage primary current (not more than 24 volts) will be sufficient. For other fuel, the best device available shall be used.

Spare Parts

616. Two extra ignitors and two extra crank pin brasses shall be furnished.

(d) Electric

Rules

617. The electrical equipment shall conform to the Standardization Rules of the American Institute of Electrical Engineers as adopted June 28, 1916, with additions and revisions.

The National Electric Code and local ordinances shall apply to the electrical material, construction, and installation, except as provided otherwise herein.

Wires, Etc.

618. The quality of the wires, cables, and insulation (except slow burning insulation) shall conform to the Railroad Specifications for Electric Wires and Cables of the American Railway Engineering Association as adopted in 1921, with additions and revisions. Wires and cables shall be subject to inspection during manufacture.

Motors

619. A.C. motors for 25 cycles and D.C. motors shall be of the mill type. A.C. motors for 60 cycles may be of the crane type. The motors

shall be totally enclosed and made as nearly weatherproof as practicable. They shall be so mounted as to admit of easy access for inspection and repairs. The frame, if practicable, shall be split, to allow the top part to be removed for taking out the armature without disturbing the mounting of the motor. The motors shall be securely supported and anchored. There shall be a close fit of the anchor bolts in the holes. If installed on the moving span, the motors shall be capable of being operated satisfactorily in any position.

Tests

620. Motors of 50 H.P. or more shall be tested at the factory by the manufacturer in the presence of the Company's Inspector. Certified copies of factory tests of all electrically operated devices shall be furnished by the Contractor.

Design of Electrical Parts

621. Electrical parts, such as wires, switches, etc., shall be designed for the currents required for the motors when they exert the normal torques called for by the torque curves, on the supposition of continuous operation for one hour through successive cycles of bridge operation. For twice the normal torques and 15-minute operation, the temperature rise of the parts shall not exceed that for one-hour operation under normal torques. The excess torques shall be taken through successive cycles of bridge operation. The allowable drop at the motor terminals shall not exceed five per cent of the supply voltage measured at the switch board.

Working Plans

622. The Contractor shall make complete working plans for the electrical equipment. The tracings shall become the property of the Company after they have been corrected to show the work as constructed. These plans shall show:

(a) Complete wiring diagram, giving size of the wires and the make and capacity of all apparatus.
(b) Complete piping diagram, giving size and location of the conduits with the number and size of wires in each.
(c) Size and location of the switchboard.
(d) Location of the lamps.
(e) Location of the controllers, limit switches, and foot switches.
(f) Size and location of resistances.
(g) The numbering of the circuits corresponding to numbered tags.
(h) A curve of the current required by the motors at the various stages of operation.

Special apparatus shall be designated by the manufacturer's name and catalogue reference.

Number of Motors

623. If the total power output at the motor pinion (under loads specified in (A) of Art. 308) to move the bridge at the required speed exceeds 25 H.P., there shall be two main operating motors, alike.

Motor Tests

624. Any motor under test shall develop the required horsepower and torque at the armature shaft. Characteristic curves showing the results of the test shall be furnished by the Contractor.

Starting Torque

625. The sum of the starting torques of the two motors (or the starting torque of the motor for a single motor installation) shall be equal to at least twice the greatest torque shown by the torque curves for the bridge operating machinery. The installing torque of alternating current motors shall be equal to at least 1¼ times the starting torque.

Speed of Motors

626. The r.p.m. of motors of 10 H.P. or more at the rated output shall not exceed 750; of the countershaft, 150. For other motors the r.p.m. shall not exceed 1,200; of the countershaft, 250.

D.C. Motors

627. Direct current motors shall be of the series type with commutating poles. They shall be designed for the service characteristics specified. Each motor shall be capable of delivering its rated output continuously for 30 minutes without exceeding 55 degrees C. rise in temperature.

If the motors are used for dynamic braking, they shall perform that function without injurious sparking or temperature rise.

A.C. Motors

628. Alternating current motors shall be of the induction type designed for the service characteristics specified. Those of more than 5 H.P. shall have slip rings. Each slip ring motor shall be capable of delivering its rated output continously for 30 minutes without exceeding 55 degrees C. rise in temperature. For squirrel cage motors the time shall be 15 minutes. Squirrel cage motors shall have high resistance rotors.

Heat tests, potential tests, and temperature corrections shall be in accordance with the Standardization Rules of the American Institute of Electrical Engineers.

Weather Protection

629. The field and armature coils of motors shall be rendered moistureproof by treatment with a special compound. Motors outside of the machinery house shall be housed in a weatherproof metal housing. This housing shall be arranged to allow the motor to be inspected and oiled, and shall be readily removable. The metal in the housing shall be galvanized and not thinner than No. 16 U.S. Standard gage.

Back-Geared Motors

630. In back-geared motors, one cast steel cut gear (bored and keyseated for attachment to the countershaft) shall be furnished with the motor. The gear ratio shall be such that the speed of the countershaft will not be more than 250 revolutions per minute. The gear and pinion shall be covered by a sheet steel or malleable iron split gear case, supported by the motor frame. An opening with a hinged cover shall be provided in the gear case for inspection and oiling.

Spare Parts

631. The Contractor shall furnish the following spare parts:

(a) A set of fuses, not less than six of each kind.

(b) A set of contacts and contact fingers for each device.

(c) One brake coil for each size of brake.

(d) One coil for each size of magnetic switch.

(e) For each size of motor:

One pinion, or one pinion and gear for back-geared motors.
One set of brushes.
One set of motor bearing linings.

For D.C. Motors:

One armature complete with shaft and commutator.
One series field coil.
One commutating field coil.

For A.C. Motors:

One rotor complete with shaft and slip rings.
One complete set of stator coils.

Controllers

632. There shall be in the operator's house one controller for the operation of each main motor, one for each rail lock motor, one for each bridge lock motor and one for each end lift motor. For manual control of motors in parallel, the controllers shall be interconnected so that all controllers will be operated simultaneously through any one controller handle manipulation. The controllers shall be so arranged that the operation of any motor may be cut out by pulling a switch without affecting the operation of any other motor.

The controllers shall be of the reversing drum or flat type. Direct current controllers shall have a magnetic blowout. The controllers shall be capable of varying and maintaining the speed of the motors throughout the entire range desired, without injurious sparking, and without shock due to sudden variation in speed. They shall be capable of doing their work under the greatest loads that may come upon the motors with a temperature rise not exceeding 30 degrees C.

633. The number of steps in controllers for main motors shall be such that the minimum or maximum motor torque will not differ by more than ten per cent from the average torque required for uniform acceleration of the bridge against all resistances.

For automatic control, there shall be no fewer than four; for manual control, no fewer than five points of acceleration.

634. Where there are two main D.C. motors, the controller shall be of the series-parallel type if the current is furnished by a storage battery. For other D.C. motors the control shall be parallel throughout. The field of interpole motors may be varied.

Resistances

635. For more than 25 amperes, rheostatic units shall be of the cast grid type. The rheostat shall be of such capacity that any part of it will carry continuously for five minutes the root-mean-square current for the heaviest cycle of motor operation with a temperature not exceeding 350

degrees C. The units or sections shall be so mounted on a steel frame as to be free from injurious vibration and to permit free circulation of air around them; and so that any unit or part of unit may be removed and replaced without disturbing the others. The units shall be insulated from their supports. For less than 25 amperes, other types of units may be used.

Remote Control

636. When the rated capacity of each motor requires more than 200 amperes, the motors shall have remote control. The motor circuits shall be made by contactors mounted on unit slate panels. The contactors shall be operated by solenoids controlled by a master controller.

Automatic and Remote Control

637. The following features apply to remote and to automatic control:

1. Direct Current.

(a) *Controller Equipment.* The controller panel shall be made of unit slate panels mounted on an angle iron frame.

Single or double-pole contactors of the shunt type for reversing the motors shall be installed. A single-pole shunt contactor shall be provided for opening the side of the line opposite to that opened by the reversing contactors.

A separate overload relay shall be provided to open each side of the line in case of overload or ground. The overload relays shall open both sides of the line. Upon tripping they shall reset by bringing the master controller to the off-point.

(b) *Master Controller.* The master controller shall be of the drum type, reversing with single handle and provided with necessary contacts and fingers for operating the contactors on the controller panel. The contacts and wearing parts shall be easily removable and replaceable. Controllers shall be provided with speed control for the motors. Controllers shall be of the automatic, reversing, magnetic contactor type, with an individual, series wound relay for each shunt wound acceleration contactor.

For parallel or series-parallel operation, the controllers shall have individual reversing switches and separate resistors for each motor with separate acceleration contactors controlled by one train of series wound acceleration relays, to prevent a direct path for current from one motor to the other.

(c) *Knife Switch.* One double-pole, single throw, mill type, fused, knife service switch shall be mounted on a controller panel for each main operating motor. A double-pole, single throw, fused, knife switch for cutting off the control circuits shall be installed.

(d) *Series Switches.* Adjusting plugs, screws, and nuts shall be easily accessible, to allow the series switches to be adjusted for closing value while the controller is operating.

(e) *Interlocks.* The reversing shunt switches shall be electrically and mechanically interlocked to prevent the closing of the reversing switches until the forward switches shall have opened. The reversing switches and the series switches shall be electrically interlocked to prevent the closing of the reversing switches while the forward switches or any series switch is closed.

(f) *Contacts.* Contacts on shunt switches and series switches shall be removable without disturbing any other part of the switch.

2. ALTERNATING CURRENT.

(a) *Controller Equipment.* The controller panel shall be made of unit slate panels mounted on an angle iron frame.

Double or triple-pole contactors of the shunt type for reversing the motors shall be installed.

An inverse time element overload relay shall be provided in each of two lines of a three-phase circuit which will open all three lines of the circuit. Upon tripping, the overload relay shall reset by bringing the master controller to the off-point. If double-pole contactors are used to reverse the motors, another contactor shall be supplied to open the other line (not opened by the reversing switches) in case of overload or ground.

(b) *Master Controller.* The master controller shall be of the drum type, reversing with single handle, and provided with necessary contacts and fingers for operating the contactors on the controller panel. The contacts and wearing parts shall be easily removable and replaceable. Controllers shall be provided with speed control for the motors.

Controllers shall be of the automatic, reversing, magnetic contactor type with an individual, series wound relay for each shunt wound acceleration contactor.

For parallel operation, the controllers shall have separate acceleration contactors connected to separate resistors for each motor. Each phase shall have its own resistors, so designed as to give balanced current in all three phases. The acceleration contactors shall be so designed, or electrically or mechanically connected, that corresponding circuits in each motor control will be made simultaneously, and that in the event of one motor being cut out the control for the motor still in use will operate satisfactorily. The motors shall have individual reversing switches.

The entire controlling apparatus must operate satisfactorily without chattering, between 80 and 105 per cent of normal line voltage at the switchboard, and must be capable of operating the bridge through continuous and successive cycles of operation. No-voltage protection, which will open the motor circuits on failure of power, shall be furnished.

(c) *Knife Switch.* One triple-pole, single throw, mill type, fused, knife service switch shall be provided for each main operating motor.

A single throw, fused, knife switch for cutting off the control circuits shall be installed. This switch shall have a pole for each wire energizing the control circuit.

(d) *Series Switches.* Adjusting plugs, screws, and nuts, including time limit adjustment, shall be easily accessible, to allow the series switches to be adjusted for closing value while the controller is in operation.

(e) *Interlocks.* The reversing shunt switches shall be electrically and mechanically interlocked to prevent the closing of the reversing switches until the forward switches shall have opened. The reversing switches and the series switches shall be electrically interlocked to prevent the closing of the reversing switches while the forward switches or any series switch is closed.

(f) *Contacts.* Contacts on shunt switches and series switches shall be removable without disturbing any other part of the switch.

Brakes

638. The main motors and end lift motors shall be provided with post brakes which are held in the set position by a spring or a weight with such force as to overcome the full load torque of the motor. The brakes for other motors may be of either the post or disc type. The friction surfaces shall be of materials which are not affected by moisture. The brakes for main motors shall be arranged to be released by shunt coil solenoids; for other motors, by series coil solenoids. The solenoids shall have ample power, and heat dissipating capacity; and shall set automatically whenever the current fails or is cut off from the motors. Disc brakes shall be dry brakes. Solenoids shall be moisture-proof. Brakes on main operating motors shall be provided with a foot-switch release for coasting purpose. Means shall be provided for releasing the brakes mechanically.

Air Brakes

639. If air brakes are used, they shall be controlled from the operator's house. The air compressor shall be electrically operated, and shall be able to compress 11 cu. ft. of free air a minute against a tank pressure of 90 lb. a square inch. The loss of pressure through the valves of the compressor shall be not more than 1½ lb. in ten minutes. The pressure at the tank shall be maintained automatically between 60 and 90 lb.

The air tank shall be cylindrical with a capacity of at least 10 cu. ft. It shall be built up of boiler plate with riveted joints. It shall show no leaks when tested at a pressure of 160 lb. a square inch.

The brake cylinder shall have a spring release capable of placing the brake in the released position automatically as soon as the air is exhausted. The cylinder shall be not less than 6 inches in diameter with a stroke of not more than 6 inches.

At a convenient place in the line carrying air to the brake cylinder, there shall be a union with a choke which will introduce a period of at least five seconds for establishing the tank pressure in the cylinder.

If the control of the air in the brake cylinder is remote and electrically operated, the arrangement of the application and release magnets shall be such that the brake will be applied in case of any power failure.

The pipe line between the compressor and the reservoir tank shall consist of not less than 50 feet of pipe. From the compressor, it shall run vertically upward to the highest point in the line. From this point, the line shall slope downward to the tank.

Emergency Brake

640. The emergency brake shall be arranged to be released by a solenoid or a motor which will hold the brake in release as long as the current is applied. Cutting off the current from the solenoid or motor or any failure of the current shall result in the instantaneous application of the brake. This brake normally shall be set and so arranged that it

must be released by the operator before starting the bridge. It shall be held in release during the entire operation unless an emergency condition arises requiring brake power in excess of that offered by the motor brakes, in which case it may be applied instantly by the operator. This portion of the equipment shall be so designed that it will not be injured if left in release indefinitely. Means shall be provided for releasing the emergency brake mechanically.

641. The emergency brake motor circuit or solenoid circuit shall be independent of the general interlocking system, and there shall be an electrical interlocking device which will prevent the use of the main motors and the emergency brake one against the other, except at the instant of closing. At closing, the brake shall be applied automatically before the power is cut off from the main motors, to prevent rebounding of the span.

The emergency brake switch shall be attached to the controller stand within easy reach of the operator. Labels shall be placed back of the switch handle to indicate the set and the released positions of the brake.

Brake Housing

642. Electrically operated brakes shall be housed.

Automatic Stops

643. The bridge lock motors and the rail lock motors shall be arranged to be stopped and their brakes to be set automatically at each end of the travel. An automatic cut-off shall be provided which will cut off the current from the main motors and set the brakes so that the span will be stopped when the end is six feet from either the closed or the fully open position. A spring opening switch shall be provided which, if held closed, will put the cut-off out of service and thus enable the bridge operator to close or to fully open the bridge.

Switchboard

644. The switches, cut-offs, circuit breakers, fuses, and meters shall be in the operator's house and mounted on an oil finished slate panel switchboard, not less than 1½ inches thick and free from metallic veins and flaws. The bottom of the board shall clear the floor by at least nine inches. There shall be a distance of at least three feet between the wall and any of the parts on the back of the switchboard. The appliances mounted on the switchboard shall be provided with plates designating their uses.

The switchboard, switches, and controlling devices shall be designed and installed with a view to the safety of the operator.

Meters—Ground Detector

645. A voltmeter and an ammeter shall be provided and installed on the switchboard. The switchboard instruments shall be illuminated. A voltmeter switch shall be provided which will allow the voltage between any two mains and the voltage between any main and the ground to be measured.

Switches

646. There shall be a main switch of the quick break type with a pole for each supply wire and a switch in each motor, light, signal, indicator, or other circuit.

Circuit Breakers and Fuses

647. An automatic circuit breaker shall be placed in the supply line. There shall be an enclosed fuse in each line to a motor, in each line to an electric brake, and in each line of lighting, signal, indicator, or other circuit. Fuses for circuits of 60 amperes or more shall have knife blade contacts.

Emergency Switches

648. Emergency switches which will free the various motors from the interlocking in emergency shall be mounted on the switchboard and shall be covered by individually sealed glass cases.

Switches

649. Switches shall be designed to carry not more than 900 amperes per square inch of cross-section. Knife switches shall be of not less than 100 amperes capacity. The blades or clips of knife switches and similar parts shall be not less than $\frac{3}{32}$ inch thick. Snap switches shall not be installed in circuits carrying more than 6 amperes. They shall be of not less than 20 amperes capacity.

Preferably, laminated switches shall not be used, but if used they shall have auxiliary carbon contacts which operate later.

Contact Areas

650. Line contact in a circuit shall be avoided wherever practicable. The current per square inch of contact area shall not exceed 50 amperes for loose contact, or 100 amperes for bolted or clamped contact.

Magnetic Switches

651. If magnetic switches are used, inverse time element overload relays, electrically and hand reset, shall be used for overload protection. Magnetic switches shall be quick acting, with wiping contacts well shielded to prevent arcing between the switch and other metal parts near. For direct current, the switches shall have magnetic blowouts. The switches shall have a minimum number of parts. Series magnetic switches shall not be used to break a current on opening.

Shunt Coils

652. If shunt coils are used, in particular with brakes and magnetic switches, the insulation shall be such as to withstand the induced voltage caused by cutting off the current without the aid of external resistance.

Circuit Breakers

653. Circuit breakers and fuses shall be designed to open the circuit when the motor is taking ten per cent more current than is required to develop twice the greatest torque shown by the torque curves for the bridge operating machinery.

Circuit breakers shall have no fewer than two poles with a common trip, overload attachments, and an under-voltage release. There shall be individual closing arms for each pole. There shall be an overload coil in each line for direct current circuits, and in each of two lines of a three-phase, three-wire circuit. The overload attachments shall open the two lines of a direct current circuit and all lines of an alternating current circuit. Tripping attachments shall be positive in action.

Circuit breakers of the under-voltage or the shunt-trip types shall not be used for limiting the travel of any mechanism.

A limit switch shall be used in conjunction with a magnetic switch or contactors to stop the motors at the end of the travel.

Protection of Contacts

654. Electrical contacts shall be protected from the weather and from accumulations of dirt.

Metal Covers

655. Metal coverings for drum switches and similar parts shall be of not less than No. 16 U.S. gage, galvanized iron. For built-up boxes, the metal shall be of not less than No. 11 U.S. Standard gage. Junction boxes preferably shall be made of malleable cast iron not less than $\frac{3}{16}$ inch thick, which will allow the conduits to be threaded into the box. The boxes must be weatherproof throughout, in particular at conduit connections, and be free from rough edges and from rough surfaces.

Cast Iron in Electrical Parts

656. Cast iron, unless malleable, shall not be used in switches and small electrical parts which are located on the bridge.

Wires

657. Wires of No. 10 B.&S. gage and larger and all wires in flexible connections shall be stranded. Wire smaller than No. 12 B.&S. gage shall not be used.

Splices

658. Splices shall be neatly and carefully made. They shall be made mechanically and electrically secure before soldering. They shall be wrapped with rubber tape and friction tape and painted with waterproof insulating varnish. Splices shall not be inside of a conduit.

Conduits

659. Wires shall be placed in metal conduits. The total area of the wires (including insulation) in any conduit shall not exceed 42 per cent of the area of the conduit.

To lessen the inductive effects, the phase wires in alternating current motor circuits shall be placed close together in one conduit. Not more than three alternating current motor circuits shall be in one conduit. A circuit in three-phase work means three wires.

Conduits shall be sherardized on the inside and the outside. Sherardized condulets, pull-out boxes, ells, and other fittings shall be used with conduits. Bends shall be used sparingly. The total angle of bending between junction boxes or condulets shall not exceed 120 degrees. If the conduit is bent, the radius of the bend to the center of the conduit shall be not less than twelve times the inside diameter of the conduit; this requirement does not apply to factory ells. Junction boxes may be used where other fittings are not suitable. Conduits and boxes shall have suitably located drain holes. The length of conduit between junction boxes or condulets shall not exceed 70 feet.

Conduits shall be so placed that dirt will not accumulate around them. There shall be at least ½-inch clearance between them. If on a horizontal surface, they shall clear the surface by at least three inches.

Flexible Connections

660. Where stationary conduits join the conduits on the moving span, flexible connections shall be installed. The flexible connections shall be connected at both ends by combination couplings to junction boxes with slate terminal boards. If the flexible connections are 20 feet or less in length, the wires shall be in flexible metal conduit; if more than 20 feet in length, the flexible connections shall be made of built-up cables with provision for carrying the weight of the wires and for mechanical protection of the wires. The wires in flexible connection shall be extra flexible.

Wires to Be Tagged

661. Wires shall be numbered and the number permanently marked on durable metal tags so that any wire may be traced from the switchboard to the motor or to the source of power.

Collector Rings

662. On swing bridges there shall be collector rings with the cables brought up to them on or through the center pivot. The collector rings shall be protected by a removable metal casing.

Rolled Steel Conductors

663. In vertical lift bridges, the current for the main operating motors shall be conveyed to and from the span through copper contact strips supported continuously by rolled steel sections weighing not less than 5½ lb. a foot. The copper strip shall have sufficient conductance to carry the full current. The contact strip shall be at least ¼ inch thick and at least 1½ inches wide. Against the contact strip a sliding shoe shall be pressed by a spring or by gravity.

Submarine Cables

664. Submarine cables shall be lead covered and steel armored. They shall be placed at least five feet below the bed of the navigable channel. The current and voltage, the number of conductors in the cable, the size and number of strands in each conductor, the length of the cable, and other data special to the location shall be as specified by the Company for each bridge. The cable shall be long enough to provide ample slack.

Indicators

665. The Contractor shall furnish and install, in the operator's house, electric light indicators which will show to the operator the various posi-

tions of the bridge, especially the fully open, fully closed, nearly open, and nearly closed positions of the bridge, and the closed and open positions of the end lifts, rail locks, and bridge locks.

Lighting

666. A complete electric lighting system shall be installed for the operator's house, stairways, signals, machinery, and the end lifting and locking apparatus. The system shall be designed and proportioned for the electric lighting service available. Wires shall be in metal conduits.

In the operator's house, there shall be fixed pendants of suitable length, with key sockets and deep cone, fire enameled, steel shades. For exterior lighting, deep bowl, fire enameled, steel reflectors, and weatherproof sockets shall be provided. The Company will furnish at the site one complete set of lamps. The Contractor shall place them in the sockets and shall be responsible for them until the acceptance of the work by the Engineer.

Circuits

667. Circuits are classified according to the following list:

1. Circuits to motors.
2. Circuits to lamps other than indicator lamps of interlocking circuits.
    - (a) Lamps for operator's house.
    - (b) Lamps for stairways, walks, etc.
    - (c) Lamps for machinery.
    - (d) Lamps for navigation.
3. Circuits for interlocking of operating machinery, including indicator lamps.

There shall be an independant circuit for each motor, for each group of lamps, and for the interlocking. The use of a common return wire will not be allowed. Each circuit shall be protected and controlled by its own fuses and switches located on the switchboard or at an equally convenient point.

(VII) MATERIALS

(a) Cast Steel

Cast Steel

701. Steel for castings shall conform to the Specifications for Steel Railway Bridges of the American Railway Engineering Association, except as provided otherwise herein.

A test to destruction on three castings selected from a lot may be substituted for the tensile test, in the case of small or unimportant castings. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt or blow annealed in the same furnace charge.

Large castings shall be hammered all over while suspended. If cracks, flaws, defects, or weaknesses appear, the casting shall be rejected.

(b) Forged Steel

Forged Steel

702. Steel for forging shall be made by the open-hearth or the crucible process and shall conform to the following chemical requirements:

Phosphorus, maximum ....0.04 per cent
Sulphur, maximum.......................................0.05 per cent

An analysis shall be made by the Contractor from a test ingot taken during the pouring of each melt. Check analyses may be made by the purchaser from drillings taken from (a), a full-sized prolongation of a forging from each melt at a point midway between center and surface, or (b), turnings from a test specimen. Both analyses shall conform to the requirements specified.

Check analyses may be made by the Engineer from a broken tension or bend test specimen. The phosphorus and sulphur content thus determined shall not exceed that specified by more than 20 per cent.

703. Annealed forged steel shall conform to the requirements in the following table:

For Forgings Whose Maximum Outside Diameter or Over-All Thickness Is Not Over 20 Inches

Size Outside Diameter or Over-all Thickness	Tensile Strength, min., lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., min., per cent		Reduction of Area, min., per cent	
			Inverse Ratio	Not under	Inverse Ratio	Not under
Not over 8 in.........	75,000	0.5 tens. str.	$\frac{1,800,000}{\text{tens. str.}}$	20	$\frac{2,800,000}{\text{tens. str.}}$	33
Over 8 to 12 in., incl...	75,000	0.5 tens. str.	$\frac{1,725,000}{\text{tens. str.}}$	19	$\frac{2,640,000}{\text{tens. str.}}$	31
Over 12 to 20 in., incl..	75,000	0.5 tens. str.	$\frac{1,650,000}{\text{tens. str.}}$	18	$\frac{2,400,000}{\text{tens. str.}}$	29

The tension test shall be made on a standard turned test specimen, ½ inch in diameter and 2 inches in gage length.

704. A specimen 1 inch by ½ inch shall bend cold 180 degrees around a diameter of ½ inch without cracking on the outside of the bend. The bending may be effected by pressure or by blows.

705. Forgings shall be free from cracks, flaws, seams, and other injurious defects.

706. Forgings shall be annealed. Before annealing, they shall be allowed to become cold after forging. They shall then be reheated uniformly to the proper temperature and allowed to cool uniformly.

707. Physical tests of forging shall be made after final treatment. Each annealing charge and each melt shall be tested.

If the tests do not show the required physical properties, the forgings may be reannealed, but not more than three times. If the tension specimen shows a fracture more than 15 per cent crystalline, a second test shall be made. If the second fracture is more than 15 per cent crystalline, the forgings shall be reannealed.

708. Test specimens shall be cut cold from the forging or from a full-sized prolongation of it. For forgings with large ends or collars, the test specimen shall be taken from a prolongation of the same diameter or cross-section as that of the forging back of the large end or collar. The axis of the specimen shall be half-way between the center and the outside, or for hollow forgings, half-way between the inner and outer surfaces. The length of the specimen shall be in the direction of the working or drawing out of the metal. Marks identifying the melt and annealing charge shall be stamped on each forging and on each test specimen by the Inspector before the specimen is cut.

(c) Tool Steel

Tool Steel

709. Tool steel shall be made by the open-hearth or the crucible process. It shall conform to the following chemical requirements:

Carbon, minimum	1.00 per cent
Phosphorus, maximum	0.04 per cent
Sulphur, maximum	0.04 per cent
Manganese, maximum	0.50 per cent

(d) Bronzes

Bronzes

710. Phosphor bronze shall be a homogeneous alloy, of crystalline structure. It shall be made from new metals, except that scrap of known composition produced by the foundry at which the bronze is cast may be used. It shall not contain sulphur. The phosphorus shall be introduced in the form of phosphor-tin or phosphor-copper. Castings shall be sound, clean, and free from blow-holes, porous places, cracks, and other defects.

711. The hardness of the finished castings shall be tested by the Brinell ball method and a record of the test furnished. The ball shall be of hardened steel 10 mm. in diameter. The load shall be 500 kg. and shall be applied for 30 seconds to a finished plane surface. No fewer than two hardness tests shall be made on each heat. A test shall be made on each trunnion bearing and on each disc.

712. The alloy shall be cast into ingots and allowed to cool, and the castings shall be poured from the remelted ingots. Care shall be exercised that the metal is not overheated and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

713. There shall be four grades.

Grade A is to be used for contact with hardened steel discs under pressures exceeding 1,500 lb. per square inch, such as are used in turntables and center bearing swing bridges.

Grade B is to be used for contact with soft steel at low speeds under pressures not exceeding 1,500 lb. per square inch, such as trunnions and journals of bascule and lift bridges.

Grade C is to be used for ordinary machinery bearings.

Grade D is to be used for gears, worm wheels, nuts, and similar parts which are subjected to other than compressive stresses.

714. The chemical and physical properties shall conform to the requirements in the following table:

ALLOY OF	GRADE			
	A	B	C	D
	Copper and tin	Copper and tin	Copper, tin and lead	Copper, tin and zinc
Copper per cent			82 max.	89 max.
Tin per cent	20 max.	17 max.	11 max.	11 max.
Lead per cent			11 max.	
Zinc per cent				2.25 max.
Phosphorus per cent	1.0 max.	1.0 max.	1.0 max. 0.7 min.	0.25 max.
Other elements per cent	0.5 max.	0.5 max.	0.5 max.	0.5 max.
Elastic limit in compression, pounds per square inch	24,000 min.	18,000 min.		
Permanent set in inches under 100,000 pounds per square inch	.06 min. .10 max.	.10 min. .20 max.		
Permanent set in inches under 50,000 pounds per square inch	To be recorded	To be recorded	To be recorded	To be recorded
Yield point in tension, pounds per square inch				To be recorded
Ultimate strength in tension, pounds per square inch				33,000 min.
Elongation in 2 in. per cent				14 min.

Cracks or other evidence of excessive brittleness in compression test specimens may be cause for rejection.

The chemical analysis of each heat shall be furnished.

715. Test specimens shall be made from coupons which are a part of the castings and which have been fed and cooled under the same conditions as the casting.

Compression test specimens shall be cylinders one inch high and of one square inch area. The elastic limit in compression shall be the load which gives a permanent set of 0.001 inch.

Tension test specimens shall be turned from a coupon not less than one inch in diameter to the form shown in Fig. 6, Specifications for Steel Railway Bridges of the American Railway Engineering Association. The diameter of the turned specimen shall be ½ inch.

716. One or more compression tests shall be made from each melt for grades A, B and C; and one compression and one tension test for grade D. For castings weighing over 100 lb. finished, the prescribed tests shall be made for each casting.

(e) Babbitt Metal

Babbitt Metal

717. Babbitt metal shall be approximately of the following composition:

Copper	3.6 per cent
Tin	89.3 per cent
Antimony	7.1 per cent

(VIII) WORKMANSHIP

Planing Girders

801. In built track girders and segmental girders of rolling bascule bridges, and in the lower flanges of the drums of rim-bearing swing bridges, the edges of the webs, side plates, and angles shall be so planed that full bearing on the track plate will be secured.

Rack and Track

802. In swing bridges, track segments shall be planed on the top and bottom and at the ends. Surfaces on which conical rollers bear shall be planed to the true bevel. The center line shall be scribed on the surface.

The toothed segments forming the rack shall be fitted accurately. Particular care shall be taken to have the pitch of the teeth at the joints accurate. The periphery of rack teeth shall be planed. The pitch line shall be scribed on the teeth.

In swing bridges, the rack segments shall be fitted to those of the track so that the center line of the track will be concentric with the pitch line of the rack.

The backs of racks which bear on metal surfaces and the surfaces in contact with them shall be planed.

Tread Plates

803. In rolling bridges, the top and bottom surfaces of the tread plates and the surfaces in contact with them shall be planed.

Rollers

804. The periphery and faces at the rim of rollers and balance wheels shall be turned, the corners shall be rounded, and the center line of the rollers and balance wheels shall be scribed on the periphery. The hubs shall be bored accurately and faced on both ends.

Pivots

805. Pivot stands and center castings of swing bridges shall be finished and fitted accurately. The base shall be faced truly at right angles to the axis and shall be turned on the circumference concentric with the axis.

Discs

806. Steel discs shall be of tool steel. They shall be fitted accurately, finished to gage, and oil tempered. After hardening, they shall be ground accurately to the final finish. The sliding surfaces of steel and phosphor-bronze discs shall be polished. Disc centers shall be assembled, fitted accurately and match-marked.

Assembling Centers

807. The complete center of a swing bridge, including rim girders, rack, track segments and rollers, shall be assembled in the shop and aligned, fitted, drilled and the parts match-marked.

Fillets

808. Shafts and trunnions shall be made with fillets where abrupt changes in section occur.

Journals

809. Journals, trunnions, linings and other rubbing surfaces shall be polished after being machined. Journals of shafts which are not cold rolled shall be turned with a filleted collar on each end.

In journals and trunnions more than eight inches in diameter, there shall be a hole bored lengthwise through the center. The diameter of the hole shall be about one-fifth of the diameter of the journal or trunnion.

Couplings

810. The faces of flange and split muff couplings shall be planed to fit.

Hubs

811. The hubs of wheels, pulleys, couplings, etc., shall be bored to a close fit on the shaft. If the hub performs the function of a collar, the end next to the bearing shall be faced. Hubs shall be bored accurately at the true center of the wheel.

Linings

812. Bearings shall be bored for the journal and finished smooth after the lining has been put in. The bearing shall be bored 1/50 inch larger than the diameter of the journal. Bearings for rack pinion shafts shall be bolted to the bracket supporting them and bored while so fastened to insure perfect alinement. The edges of oil grooves and the edges of linings shall be rounded.

Bronze linings shall be turned on the outside to fit the bored hole in the bearing.

Babbitt metal shall be poured in the bearings in such a way that the thickness of the lining after boring will be uniform.

Bearings

813. The rubbing and bearing surfaces and the joints between cap and base of bearings shall be finished. The holes in cap and base shall be drilled. The holes in bearings for bolts fastening them to their supports shall be drilled $\frac{1}{32}$ inch larger than the bolts. The holes in the supports shall be reamed to fit after the bearings have been adjusted.

Gear Teeth

814. The teeth of gears transmitting power for the operation of the bridge, bevel gears, and wheels in the gearing of any motor, shall be machine cut. The periphery and ends of teeth of gears shall be turned. The pitch circle shall be scribed on the teeth.

Bevel Gears

815. The teeth of bevel gears shall be cut by a planer having a rectilinear motion in lines through the apex of the cone. Rotating milling cutters shall not be used for making bevel gears.

Machine Molding

816. Uncut teeth shall be machine molded.

Worms and Worm Wheels

817. Threads on worms shall be machine cut and the teeth of worm wheels shall fit the worm accurately with surface or line contact.

Keys and Keyways

818. Keys shall be planed and keyways machine cut. The finish of the keys and keyways shall be such as to give the key a driving fit on the

sides. Tapered keys shall bear on the top, bottom and sides; parallel faced keys on the sides only.

Castings

819. Castings shall be cleaned and all fins and other irregularities removed so that they will have clean, smooth surfaces, suitable for this class of work. Castings which are to be attached to structural steel or other castings shall have their contact surfaces finished. Unfinished edges of bases, ribs and similar parts, shall be neatly cast with rounded corners. Inside angles shall have proper fillets. Bosses shall be finished to the correct plane.

Bolt Holes and Turned Bolts

820. Holes for unfinished bolts shall be drilled or reamed not more than $\frac{1}{16}$ inch larger in diameter than the bolt. The diameter of the shank of turned bolts shall be at least $\frac{1}{16}$ inch larger than the diameter of the threaded portion. The bolt shall be $\frac{1}{64}$ inch smaller in diameter than the bolt hole.

Assembling Machinery

821. If practicable, machinery parts shall be assembled on the supporting members in the shop. They shall be alined and fitted, and holes in the supports shall be drilled with the members in correct relative position. The members shall be match-marked both to the supports and to each other, and re-erected in the same relative positions. If assembling is not practicable, the holes in the supports shall be left blank and drilled in the field after the machinery parts are assembled and alined.

Sheaves

822. The grooves in the sheaves shall be turned. The shape of the grooves shall conform as closely as feasible to the rope section so that while the ropes shall run freely in the grooves, the sides of the grooves shall prevent the wire ropes from flattening under static loads, as when supporting counterweights. Built sheaves shall be assembled and permanently riveted before the groves are turned.

Grooves in Trunnions

823. The grooves in the surfaces of trunnions and similar large bearings shall be machine cut. Small inequalities may be removed by chipping and filing. The grooves shall be smooth, especially the rounded corners.

Holes for Sheaves for Vertical Lift Bridges

824. In vertical lift bridges, the holes in the girders and columns for the bolts connecting the main sheave bearings to their supporting girders, shall be drilled from the solid through cast iron or steel templates on which the bearings were set and accurately alined when the holes in the bearings were bored. The bolt holes and the bolts shall be turned to the same diameter and the bolts driven to place without injury to them, the bearings, the girders, or the columns.

Air Buffers

825. The workmanship on air buffers shall be so accurate that the weight of the cylinder and its attachments will be sustained by the confined air for six minutes, with a piston travel not more than that which

occurs during the closure of the bridge. The valves must be closed and the buffers balanced so that the whole weight is carried by the piston rod.

(IX) ERECTION

901. The Specifications for the Erection of Steel Railway Bridges of the American Railway Engineering Association shall apply to the erection of movable bridges, with additions specified herein.

Protection of Parts

902. Parts which are protected from the weather in the finished structure shall be protected in the field during erection by housing or equivalent means. This applies in particular to electrical parts.

903. Rubbing surfaces of trunnions and machinery bearings shall be protected by metal thimbles packed with oil-soaked waste.

904. Wire ropes shall be housed and stored at least 18 inches above the ground. The ropes shall be kept free from dirt, cinders, and sand. During erection, the ropes shall not be pulled through dirt, or bent into sharp angles or kinks.

Lubrication

905. The counterweight ropes and the operating ropes shall be given two coats of dressing, with an interval of one month between the coats. The dressing shall not be applied in an atmospheric temperature below 40 degrees Fahr. The Contractor, during erection, in particular just before the final test, shall lubricate the sliding parts and fill all grease cups.

Channel Lights

906. During erection and in taking down the old span, the Contractor shall place and maintain navigation lights and signals, in occordance with the government requirements, for the protection of the falsework, as well as navigation.

Erection of Machinery

907. The machinery shall be erected by men skilled in the work. Special care shall be given to the alinement of trunnion bearings.

Testing of Machinery

908. Before the main operating machinery is connected for transmitting power, it shall be given an idle run of 8 hours.

909. The end lifting devices shall be adjusted to produce a lift equal to the deflection caused by the negative end reaction of the live load and impact plus 25 per cent of their sum.

910. The Contractor shall adjust the counterweight so that the span will be properly balanced.

Bridge Operator

911. For a power operated bridge, the Contractor shall provide at his own expense, a competent man to supervise the operation of the bridge for a period of 30 days after acceptance. The man shall instruct the employees of the Company in the operation of the bridge.

(These specifications are available in pamphlet form with a complete index.)

[1]REQUIREMENTS FOR THE PROTECTION OF TRAFFIC AT MOVABLE BRIDGES

The protective appliances at movable bridges consist in devices for insuring that the bridge is in proper position, and the track in condition for the passage of trains or for reduction to a minimum of the damage in case of trains not stopping when track is not in condition for passage of trains; also the usual devices for protection against damage in case of derailment.

The protective devices may be classified under the headings:

(a) Interlocking power and bridge devices.
(b) Bridge surfacing, alining and fastening devices.
(c) Rail-end connections.
(d) Signaling and interlocking.
(e) Guard rails.

Interlocking Power and Bridge Devices

(a) Interlocking the bridge devices so that their movements must follow in a predetermined order to protect the bridge machinery.

Bridge Surfacing, Alining and Fastening Devices

(b) Movable bridges should be equipped with proper mechanism to surface and aline them accurately and fasten them securely in position. This condition can be secured by the use of effective end lifts in case of swing bridges, and by proper end locks in case of vertical lift bridges.

Rail-End Connections

(c) Rail ends may be mitered or cut square. Mitered rails where lapped should retain the full thickness of the web to the points. The points should be trailing to normal traffic where possible; on single-track bridges the points should be trailing to traffic entering the movable span.

Where rail ends are cut square or mitered and not lapped, they should be connected by sliding sleeve or joint bars or by easer rails to carry the wheels over the opening between the end of bridge and approach rails.

Signaling and Interlocking

(d) If trains are to proceed over movable bridges which are in service, without first stopping, interlocking should be installed which will provide that the span, tracks and switches within the limits of the plant are locked in the proper position. This will require:

(1) Locking bridge devices.

(2) Locking providing for the proper order of operation of signaling devices, such as signals, switches and derails.

This interlocking will require the following order of operation:

Before Opening Bridge	*Before Operating Trains Over Bridge*
1. Display stop signals.	1. Lock bridge and rail devices.
2. Unlock rail and bridge devices.	2. Display clear signals.

Since there are various types and designs of movable bridges and various devices for each of those types, and also various designs and types of signaling devices, as well as various locations, from which they all may be interlocked and operated, a typical example only of the detail order of operations is given; viz., a swing bridge with all its devices operated from one location on the span, having home and distant signals, derails, etc.:

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[1] Adopted, Vol. 17, 1916, pp. 101, 172, 800.

To Open Movable Bridge	*To Pass Trains Over Movable Bridge*
1. Display stop signals.	1. Close bridge.
2. Unlock derails.	2. Insert bridge surfacing, alining and fastening devices.
3. Open derails.	3. Insert rail-end connections.
4. Uncouple interlocking connections.	4. Operate power-controlling device to position preventing application of power to bridge machinery.
5. Unlock rail-end connections.	5. Lock bridge surfacing, alining and fastening devices.
6. Unlock bridge surfacing, alining and fastening devices.	6. Lock rail-end connections.
7. Operate power-controlling device to position permitting application of power to bridge machinery.	7. Couple interlocking connections.
8. Withdraw rail-end connections.	8. Close derails.
9. Withdraw bridge surfacing, alining and fastening devices.	9. Lock derails.
10. Open bridge.	10. Display clear signal.

DERAILS.—The above example of order of operation includes derailing switches, but their use is not recommended in all cases. Each situation must be given special study with respect to: (a) the use of derails, smash boards or similar devices; (b) their location with respect to drawspan, and (c) the use and length of guard rails.

Guard Rails

(e) Guard rails should be provided as for fixed bridges, except for the necessary breaks at the ends of the movable span. Obstructions to derailed wheels which are guided by the guard rails should be reduced to a minimum.

The rails and attachments should be separated from the metallic structure so track circuits may be successfully operated the entire length of the bridge.

The various bridge devices should be so designed that Signal Section, A. R. A. interlocking apparatus may be used.

Electric and time locking are regarded as adjuncts.

[4]SPECIFICATIONS FOR THE ERECTION OF STEEL RAILWAY BRIDGES

For Fixed Spans Less Than 300 Feet in Length

FOREWORD

These Specifications lay down general rules for erection, with specific instructions covering work ordinarily encountered in railway bridge erection. For work of a special nature, or work to be done under unusual conditions, they may be modified to adapt them to the special requirements. They are intended for a guide in erection by railway company forces as well as for a basis for contracts.

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[4] Adopted, Vol. 13, 1912, pp. 83, 935; Vol. 24, 1923, pp. 146, 1143.

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13	Assembling Steel.
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20 and 21	Removal of Old Structure and Falsework.
22	Superintendence and Workmen.
23	Interference with Traffic.
24	Company Equipment.
25	Work Train Service.
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27	Inspection.
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INFORMATION TO BE GIVEN BIDDERS

		Article
1.	A copy of the agreement form	1
2.	A set of general and design plans of the proposed structure, with estimated quantities	5
3.	A plan or description of the structure to be replaced, with estimated quantities	2
4.	A statement showing the name of, and distance to, the station where the material will be delivered, whether loaded or unloaded, the nature and amount of traffic, and the sidetrack and storage facilities to be furnished to the Contractor	6
5.	What transportation will be furnished?	
6.	What work train service will be furnished?	25
7.	Will conductor or pilot service be furnished?	23
8.	What rolling equipment will be furnished?	24
9.	Shall the Contractor furnish and place the falsework?	8
10.	Shall the Contractor frame and place the timber deck, etc?	17
11.	Shall the Contractor place the track rails and tie-plates?	17
12.	Will the old structure be scrapped or re-erected?	20

13. Shall the Contractor load the falsework material and material from old structure on cars for shipment or pile it at the site?........20
14. The probable date when the structure will be ready for erection.
15. Shall the bidder furnish a brief description of the method of erection he proposes to follow?
16. Shall the field painting be done by the Contractor? 19

Definitions of Terms

1. The term "Engineer" refers to the Chief Engineer of the Company or his subordinates in authority. The term "Inspector" refers to the Inspector or Inspectors representing the Company. The term "Company" refers to the Railway Company or Railroad Company party to the agreement. The term "Contractor" refers to the erection contractor party to the agreement.

Work to Be Done

2. The Contractor shall erect the metal work, make all connections and adjustments, remove the old structure and falsework, and do all work required to complete the bridge or bridges, as covered by the agreement, in accordance with the plans and these specifications.

Drawings to Govern

3. Where the drawings and the specifications differ, the drawings shall govern.

Plant

4. The Contractor shall provide all tools, machinery, and appliances, including drift pins and fitting up bolts, necessary for the expeditious handling of the work. The Contractor shall protect the Company against claims on account of patented devices or parts used by him on the work.

Plans

5. The Company will furnish complete detail plans for the bridge or bridges to be erected, including shop details, camber diagrams, erection diagrams, match-marking diagrams, list of field rivets and bolts, and copy of shipping statements showing a full list of parts and weights.

Delivery of Materials

6. The Contractor shall receive all materials entering into the finished structure, free of charge at the place designated, loaded or unloaded, as specified in the information given bidders.

Handling and Storing Materials

7. The Contractor shall unload material promptly upon delivery, otherwise he shall be responsible for demurrage charges. Stored material shall be piled securely outside the tracks, and no material shall be placed closer than six feet to the near rail. Material shall be placed on skids, above the ground. It shall be kept clean and properly drained. Girders and beams shall be placed upright and shored. Long members, such as columns and chords, shall be supported on skids placed near enough together to prevent injury from deflection. The Contractor shall check all material turned over to him against shipping lists and report promptly

in writing any shortage or injury discovered. He will be held responsible for the loss of any material while in his care, or for any damage resulting from his work.

Falsework

8. Unless otherwise provided, the Contractor shall prepare and submit to the Engineer for approval, plans for falsework, or for changes in an existing structure necessary for maintaining traffic. The falsework shall be properly designed and substantially constructed and maintained for the loads which will come upon it. Approval of the Contractor's plans shall not be considered as relieving the Contractor of any responsibility. Temporary structures or falsework placed by the Company, if suitable, may be used by the Contractor.

Masonry

9. The Company will construct the masonry to correct lines and elevations, and will establish the lines and elevations required by the Contractor for setting the steel.

Bearings and Anchorage

10. Bed plates, bolsters, and shoes shall be set level in exact position. They shall be given full and even bearing by setting them on a layer of Portland cement mortar or dry cement, or by tightly ramming in rust cement after blocking them accurately in position, as directed by the Engineer.

11. The Contractor shall drill the holes and set the anchor bolts, except where the bolts are built into the masonry. The bolts shall be set accurately and fixed with Portland cement grout completely filling the holes.

Methods and Equipment

12. Before starting work, the Contractor shall advise the Engineer fully as to the method he proposes to follow, and the amount and character of equipment he proposes to use, which shall be subject to the approval of the Engineer. The approval of the Engineer shall not be considered as relieving the Contractor of the responsibility for the safety of his method or equipment or from carrying out the work in full accordance with the plans and specifications. No work shall be done without the sanction of the Engineer.

Assembling Steel

13. All parts shall be accurately assembled as shown on the plans and any match-marks carefully followed. The material shall be carefully handled so that no parts will be bent, broken or otherwise damaged. Hammering which will injure or distort the members will not be permitted. Bearing surfaces and surfaces to be in permanent contact shall be cleaned just before the members are assembled. Unless erected by the cantilever method, truss spans shall be erected on blocking so placed as to give the trusses proper camber until all tension chord splices are fully riveted and all other truss connections pinned and bolted. Rivets in splices of butt joints in compression members shall not be driven until the span has been swung. Splices and field connections shall have one-half of the holes

filled with bolts and cylindrical erection pins (half bolts and half pins) before riveting. Splices and connections carrying traffic during erection shall have three-fourths of the holes so filled.

Fitting up bolts shall be of the same nominal diameter as the rivets, and the cylindrical erection pins shall be 1/32-inch larger.

Riveting

14. Riveting preferably shall be done with pneumatic riveters and buckers. Rivets larger than 7/8-inch in diameter shall not be driven by hand. Connections shall be accurately and securely fitted up before the rivets are driven. Light drifting will be permitted to draw the parts together, but drifting to match unfair holes will not be permitted. Unfair holes shall be reamed or drilled. Rivets shall be heated to a light cherry color, and in driving shall be upset to completely fill the holes. Heads shall be full and symmetrical, and concentric with the shank, and shall have full bearing all around. They shall be of the same shape and size as the heads of the shop rivets. Rivets shall be tight and shall grip the connected parts securely together. No recupping or caulking will be permitted. Rivets shall not be overheated or burned. In removing rivets, the surrounding metal shall not be injured; if necessary, rivets shall be drilled out. Cup faced dollies, fitting the head closely to insure good bearing, shall be used.

Bolted Connections

15. In bolted connections, bolts shall be drawn up tight and threads burred.

Pin Connections

16. Pilot and driving nuts shall be used in driving pins. They will be furnished by the Company and shall be returned to the Company on completion of the work. Pin nuts shall be screwed up tight and threads burred.

Deck

17. Where so specified, the ties, guard timbers, guard rails, fire decking, concrete decking, waterproofing, ballast, and deck planking, and the track rails and tie plates, shall be placed by the Contractor. The timber deck shall be placed in accordance with the Company's plans. If treated timber is used, the Company will deliver it properly framed to the Contractor. If untreated, it shall be framed by the Contractor. The ties shall be framed to give a full and even bearing on the girders and under the rails. The guard timbers shall be dapped and framed to a snug fit over the ties and fastened as shown on the plans. If necessary to do any framing or cutting of treated timber, the resulting surfaces shall be given a brush treatment with wood preservative, as directed by the Engineer. Where concrete decking is used, or waterproofing is required, the specifications therefor will be furnished by the Company.

Misfits

18. Corrections of minor misfits and a reasonable amount of reaming and cutting of excess stock from rivets will be considered a legitimate

part of the erection. Any error in shop work which prevents the proper assembling and fitting up of parts by the moderate use of drift pins or a moderate amount of reaming and slight chipping or cutting, shall immediately be reported to the Inspector, and his approval of the method of correction obtained. The correction shall be made in the presence of the Inspector, who will check the time and material. The Contractor shall render within thirty days an itemized bill for such work of correction for the approval of the Engineer.

Painting

19. The heads of field rivets shall be given a coat of the shop paint by the Contractor. This painting shall not be done until the Inspector has examined the rivets and found them satisfactory. The tops of stringers and girders which are to carry ties shall be given one coat of field paint.

If the field painting is to be done by the Contractor, the specifications therefor will be furnished by the Company.

Removal of Old Structure and Falsework

20. The Contractor shall dismantle the old structure and falsework and load the material on cars for shipment, or pile it neatly at a site immediately adjacent to the tracks, at an elevation convenient for future handling, as directed by the Engineer. When the old structure is of iron or steel and is to be used again, it shall be dismantled without unnecessary damage and the parts match-marked.

21. The Contractor shall remove the piling to the surface of the ground, and all debris and refuse resulting from his work, leaving the premises in good condition.

Superintendence and Workmen

22. During the entire progress of the work the Contractor shall have a competent foreman or superintendent in personal charge of the work. Instructions given to the foreman or superintendent shall be considered as given to the Contractor. All work shall be done by skilled, competent workmen.

Interference With Traffic

23. The Contractor shall conduct his work in such a manner that the track, while in service, will be safe and clear for the passage of trains. Tracks shall be disturbed or removed for the prosecution of the work during such times only as allowed by the Company. While the Contractor is actively engaged in the erection, trains will be required to approach the bridge prepared to come to a stop before crossing and will proceed only on signal. During the time the Contractor operates his equipment on the tracks or has occasion to make the tracks unsafe for the operation of trains, his operations will be in charge of a conductor or pilot who will arrange and control the train movements.

Company Equipment

24. When the agreement provides that the Company shall furnish equipment to the Contractor, such as flat cars, water cars, bunk cars, etc., the Contractor shall repair all damage to such equipment furnished for his use and return it in as good condition as when he received it.

Work Train Service

25. When, under the agreement, work train or engine service is furnished the Contractor without charge, the Contractor shall state in his bid the number of days such service will be required. Any excess over the time specified in this bid shall be paid for by the Contractor at the Company's schedule of rates.

Risk

26. The Contractor shall be responsible for loss of or damage to materials, for all damage to persons or property, and for casualties of every description caused by his operations during the progress of the work. Injuries or losses due to events beyond the control of the Contractor shall not be borne by him unless they occurred because of his dilatory methods in handling the work, extending the time beyond the time limit designated in the agreement.

Inspection

27. The work shall be subject at all times to inspection by the Engineer.

Laws and Permits

28. The Contractor shall comply with Federal, State and local laws, regulations and ordinances, and shall obtain at his own expense the necessary permits for his operations.

[5]PRINCIPLES FOR DETAILED DESIGN OF FLASHING, DRAINAGE, REINFORCEMENT AND PROTECTION FOR WATERPROOFING PURPOSES

General

(1) The following applies only to membrane waterproofing, as the "integral method" is not recommended for waterproofing railway bridge floors.

(2) The structure should be designed so that it can be waterproofed and it should be adaptable to waterproofing by ordinary methods and materials.

Good workmanship being vital to the success of waterproofing, the design should be such that extraordinary precautions or methods will not be necessary to secure good results.

(3) Strength and stiffness are desirable features in a structure which is to be waterproofed.

The lack of these may permit destructive stresses in the waterproofing. Very shallow floors, such as shown in Fig. 3 and 4, should be avoided wherever possible.

(4) The structure and its construction and expansion joints, drainage and waterproofing, should be designed together, considering their separate and combined functions, so that each will help to secure a waterproof structure.

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[5] Adopted, Vol. 22, 1921, pp. 395, 1019.

If any necessary feature is overlooked, it may be difficult, if not impossible, to provide a remedy after trouble appears.

(5) Due regard should be had for the available methods and materials of construction.

Traffic conditions, climate and prevailing markets or supplies, might thus control the design. Wherever possible, waterproofing under traffic should be avoided.

(6) All waterproofed surfaces should be easily accessible, and as simple and smooth as possible; hence features should be avoided which would increase the difficulty of securing waterproof construction, such as open spaces, joints, holes, seams, or projections.

The deck bridges shown in Fig. 15 and 16 lend themselves more readily to successful treatment than the trough floors, Fig. 2, 3 and 4, or the through bridges, Fig. 8, 9, 10, 11 and 13.

(7) Concrete bridge floors should be of ample strength and thickness and of dense non-porous construction.

Special attention should be given to providing the correct amount and disposition of the reinforcement, and to securing the proper amount of water used in mixing. (See Fig. 5 to 10, 13, 15 and 16.)

(8) Where contraflexure would injure the waterproofing, special details should be provided, such as elastic joints. (See Fig. 7 and 15.)

(9) Minimize the number of construction joints in the structure, provided an ample number of workable expansion joints can be introduced.

Concrete bridge floors should, where practicable, be built in one continuous operation for each track.

Drainage

(10) Adequate drainage should be provided by means of suitable grades which will shed water by the easiest or most direct route. One per cent is a minimum desirable grade, but the grades away from points which are difficult to waterproof should be correspondingly increased.

While sewer and gutter grades may be considerably less than one per cent, bridge floors, especially if ballasted, are subject to clogging by ashes, cinders, etc., and hence require steeper slopes to secure satisfactory drainage. (See Fig. 1, 2, 3, 4, 8 and 15.)

11. Avoid pockets which cannot be easily drained.

Water with only a slight head may find an outlet through the waterproofing, which otherwise might be tight. Standing water is undesirable on a waterproofed bridge floor, from its destructive effect, both as a solvent and also on account of frost action.

(12) Where gutters or pipes are necessary, they should be of durable material, of ample size, easy of access to install and maintain, and protected against clogging or damage.

The grades should be enough to secure quick and entire escape of the water. Corrugated metal pipes are satisfactory where exposed to alternate freezing and thawing. Where sudden considerable variations in temperature occur, it is not desirable to encase drain pipes in concrete. Cleanouts and manholes should be provided where pipes cannot otherwise be cleaned. (See Fig. 3, 4, 8, 10, 12, 14, 15 and 16.)

(13) Provide free exits for the harmless escape of drainage.

Such drainage should not be allowed to disfigure the structure nor to injure persons or property. Icicles may be prevented by a basket of rock salt inserted in the top of the drain pipe. (See Fig. 3, 4, 11, 12, 14, 15 and 16.)

14. Avoid features which would induce or permit capillary action.

For example, where the waterproofing extends up under the top of flange or beneath a flashing angle, it is very desirable to make the water drip off the edge, rather than allow it to follow the under surface and be drawn into the crack. (See Fig. 6, 7, 8 and 16.)

(15) Where possible, locate edges and joints above the highest probable water level.

Edges of the waterproofing, either at parapets or where it joins the webs of through girders, should be at least as high as the base of rail, and preferably higher than the top of rail. Joints in the floor should be located so that the grades slope away from the joint.

Reinforcement

(16) Reinforcement of the structure should be suitably disposed, and ample in strength to prevent cracks or distortion which would injure the waterproofing. (See Fig. 6, 8, 9, 10, 13, 15 and 16.)

Reinforcement should be protected against destructive agencies such as electrolysis, brine, etc.

(17) Cloths, felts or fibers should be capable of holding the waterproofing pitch where placed and should be durable, strong and flexible.

(18) Wire mesh or sheet metal reinforcement for the membrane should be of durable material, flexible where necessary, and intimately bonded or introduced so that the waterprofing and reinforcement act together. (See Fig. 7 and 15.)

(19) Necessary breaks in the surface of waterproofing or flashing, such as for drain pipes, or at construction or expansion joints, should be reinforced with extra flashing material. (See Fig. 7 and 15.)

Flashing

(20) Metal flashing should be of material which is non-corrosive, and should be insulated or protected against electrolytic action at points of contact with steel members of the structure. (See Fig. 5, 7, 8, 13 and 15.)

(21) Flashing should be of material which can be applied readily, and should retain the position in which it is placed when subjected to actual conditions of service and temperature.

(22) Flashing should be firmly attached in its proper position, so that it cannot easily be displaced or removed. (See Fig. 13 and 15.)

(23) The edges of waterproofing and flashing should be protected against drip, percolation and capillary action. (See Fig. 5, 6, 7, 8, 9, 10, 11, 13 and 15.)

(24) Joints between concrete and other material should be grooved and filled with an elastic expansion joint cement. (See Fig. 1 and 9.)

Protection

(25) Waterproofing and flashing should be protected, *as soon as possible after installation,* against mechanical injury, excessive temperature, chemical action and deterioration caused by exposure to light and air.

(26) The protecting covering should be dense, hard, durable and easy to apply.

It is recommended to use on flat surfaces one of the following:

(a) Brick laid in cement mortar or served with hot pitch.
(b) Plain or reinforced cement mortar.
(c) Plain or reinforced concrete.
(d) Bituminous mastic.

For surfaces with considerable slope, mastic is not satisfactory, being difficult to apply and also to retain in place.

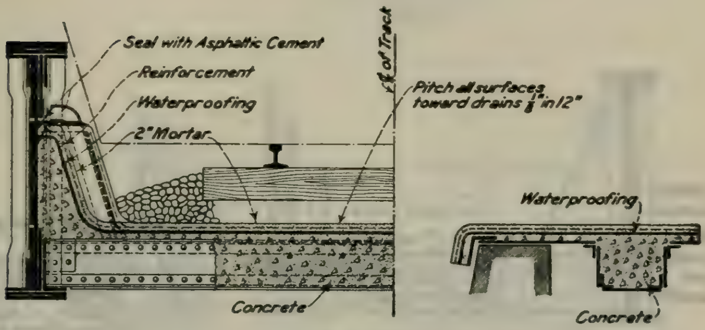
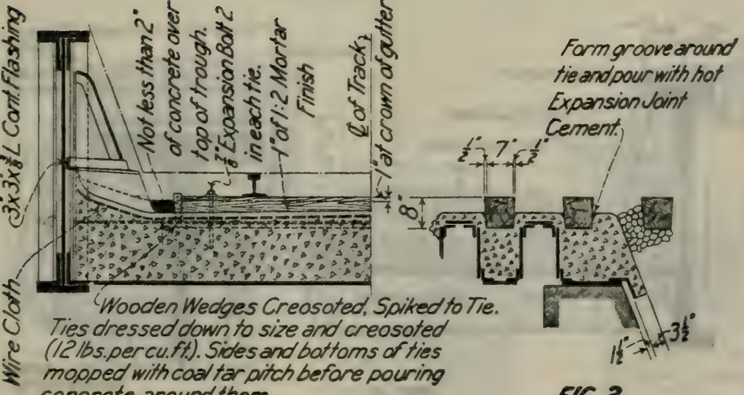


FIG. 1


3"x3"x3/8" L Cont. Flashing
Wire Cloth
Not less than 2" of concrete over top of trough.
7/8" Expansion Bolt 2 in each tie.
1" of 1:2 Mortar Finish
℄ of Track
1" at crown of gutter
8"
1/2"
7"
1/2"
Form groove around tie and pour with hot Expansion Joint Cement.
1 1/2"
3 1/2"

Wooden Wedges Creosoted, Spiked to Tie. Ties dressed down to size and creosoted (12 lbs. per cu. ft.). Sides and bottoms of ties mopped with coal tar pitch before pouring concrete around them.

FIG. 2

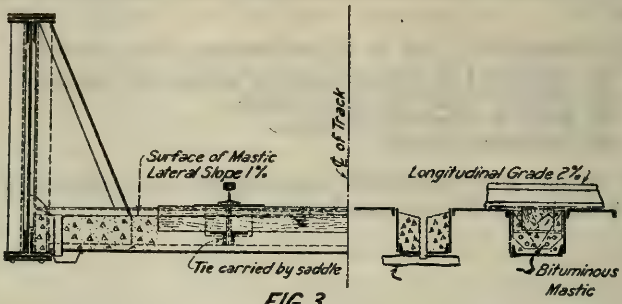


FIG. 3

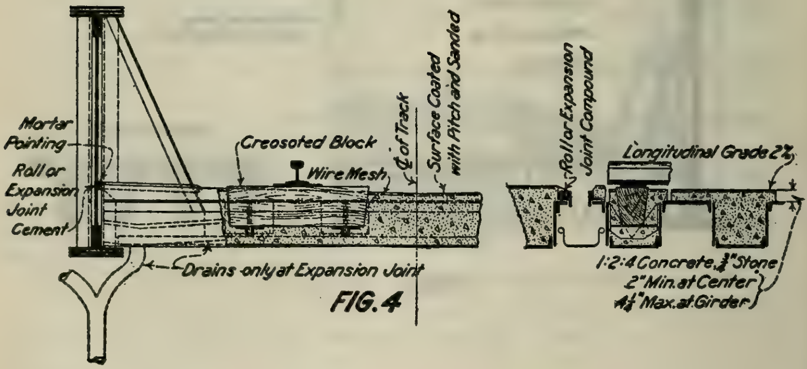


FIG. 4

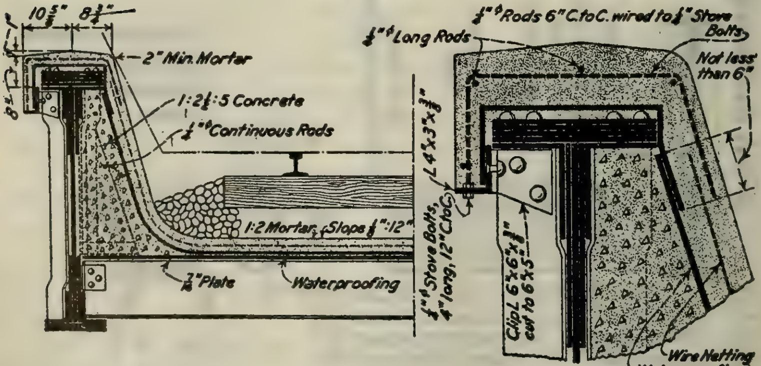


FIG. 5

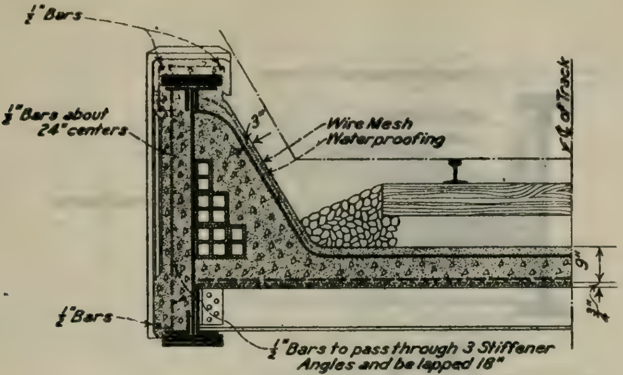

½" Bars
½" Bars about 24" centers
3"
Wire Mesh
Waterproofing
℄ of Track
9"
½"
½" Bars
½" Bars to pass through 3 Stiffener Angles and be lapped 18"

FIG. 6

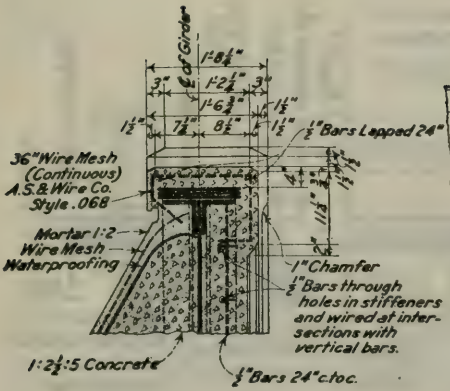
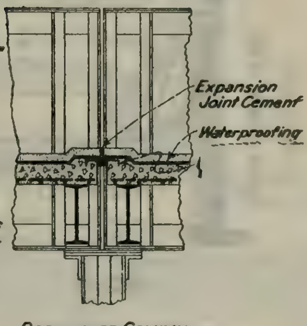


FIG. 7



DETAIL OVER COLUMN BENT

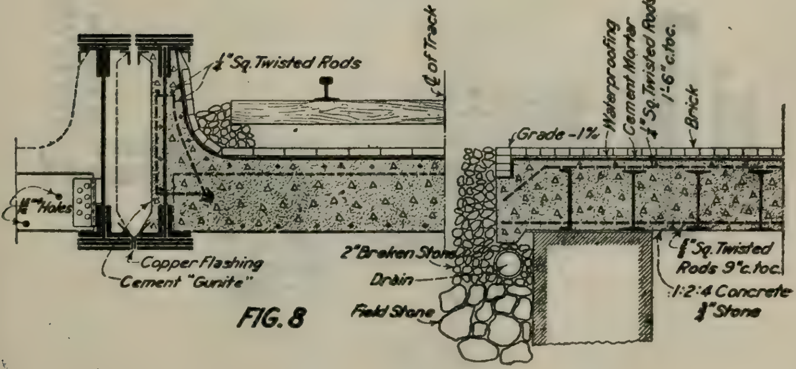


FIG. 8

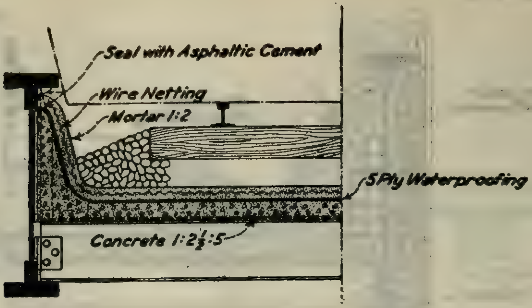


FIG. 9

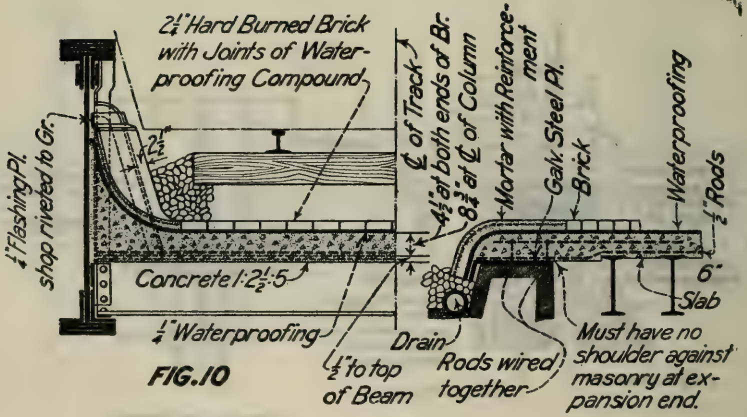

2¼" Hard Burned Brick with Joints of Waterproofing Compound
¼" Flashing Pl. shop riveted to Gr.
2½"
℄ of Track
4½" at both ends of Br.
8¾" at ℄ of Column
Mortar with Reinforcement
Galv. Steel Pl.
Brick
Waterproofing
½" Rods
6"
Slab
Concrete 1:2½:5
¼" Waterproofing
½" to top of Beam
Drain
Rods wired together
Must have no shoulder against masonry at expansion end.

FIG. 10

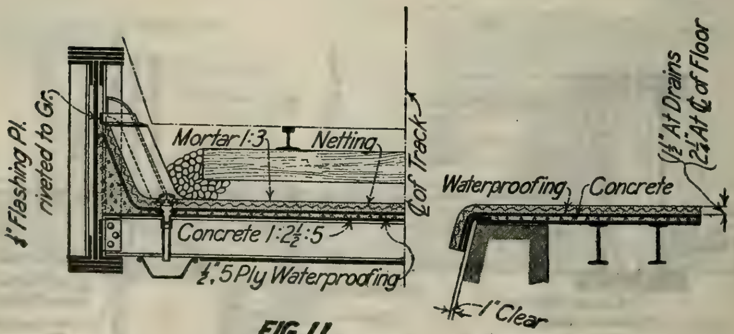
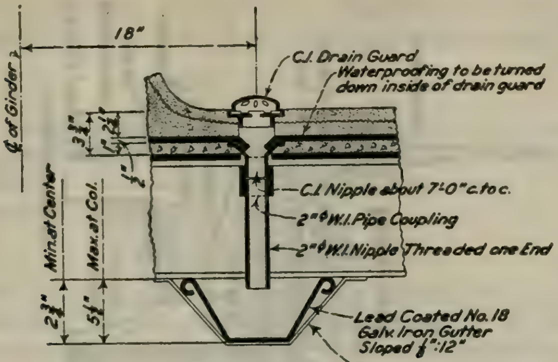


FIG. 11


18"
℄ of Girder
C.I. Drain Guard
Waterproofing to be turned down inside of drain guard
3¼"
2¼"
1"
⅛"
C.I. Nipple about 7'-0" c. to c.
2"ϕ W.I. Pipe Coupling
2"ϕ W.I. Nipple Threaded one End
Min. at Center
Max. at Col.
2¾"
5¼"
Lead Coated No. 18 Galv. Iron Gutter Sloped ⅛":12"
1½×⅛" Straps, 3'-6" c. to c.

DETAIL AT DRAIN

FIG. 12

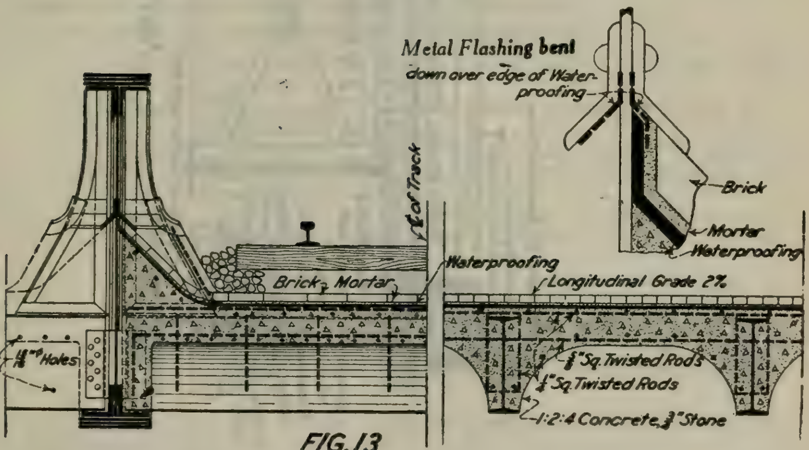


FIG. 13

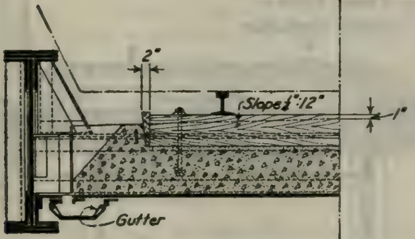


FIG. 14

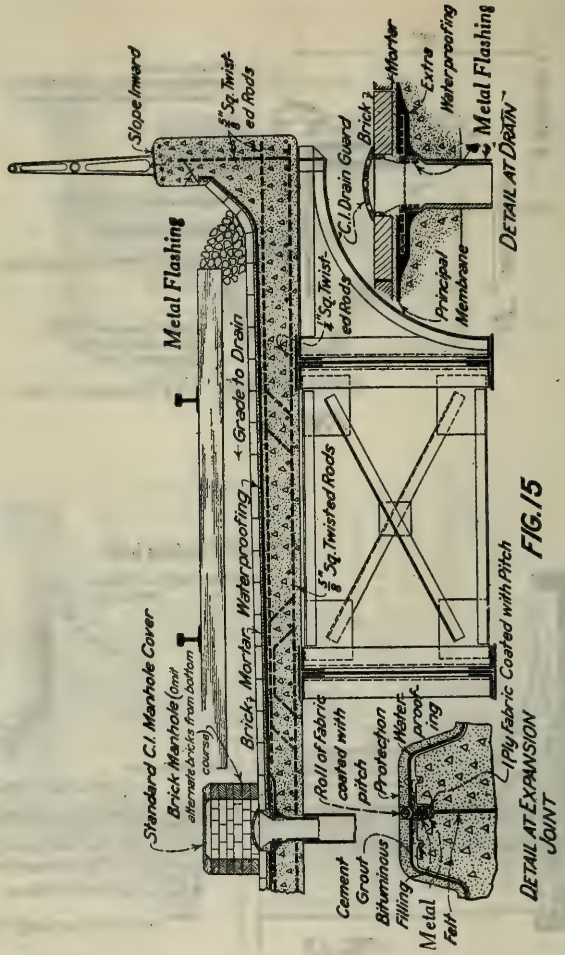

Slope Inward
5/8" Sq. Twisted Rods
Metal Flashing
Grade to Drain
Waterproofing
Brick, Mortar
5/8" Sq. Twisted Rods
1/4" Sq. Twisted Rods
C.I. Drain Guard
Brick
Mortar
Extra Waterproofing
Metal Flashing
Principal Membrane
DETAIL AT DRAIN
Standard C.I. Manhole Cover
Brick Manhole (omit alternate bricks from bottom course)
Roll of Fabric coated with pitch (Protection)
Waterproofing
1 Ply Fabric Coated with Pitch
Cement Grout
Bituminous Filling
Metal
Felt
DETAIL AT EXPANSION JOINT

FIG. 15

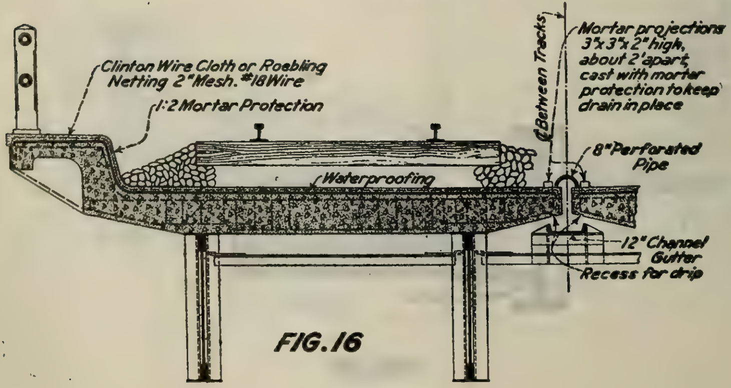

Clinton Wire Cloth or Roebling Netting 2" Mesh. #18 Wire
1:2 Mortar Protection
Waterproofing
℄ Between Tracks
Mortar projections 3"x3"x2" high, about 2' apart, cast with mortar protection to keep drain in place
8" Perforated Pipe
12" Channel Gutter
Recess for drip

FIG. 16

*SPECIFICATIONS FOR THE WATERPROOFING AND DRAINAGE OF SOLID-FLOOR RAILWAY BRIDGES

(I) GENERAL

1. These specifications apply to membrane waterproofing, which is the only kind recommended for solid-floor railway bridges. The waterproofing shall consist of a membrane covered by a protection course of brick, concrete, or asphalt mastic.

(II) DESIGN OF BRIDGE

Bridges should be designed in accordance with the "Principles for Design of Flashing, Drainage, Reinforcement and Protection for Waterproofing Purposes" of the American Railway Engineering Association.

(III) TYPES OF WATERPROOFING

3. The waterproofing membrane shall be made up of layers of bitumen-treated cotton fabric, or felt and cotton fabric, with alternate moppings of bitumen, either asphalt or coal-tar pitch.

The following types of membrane are recommended:

Type A. Two layers of asphalt-treated cotton fabric and three moppings of asphalt.
Type B. Three layers of asphalt-treated cotton fabric and four moppings of asphalt.
Type C. Two layers of asphalt-treated felt, one middle layer of asphalt-treated cotton fabric, and four moppings of asphalt.
Type D. Two layers of pitch-treated felt, one middle layer of pitch-treated cotton fabric, and four moppings of coal-tar pitch.
Type E. Four layers of asphalt-treated felt, one middle layer of asphalt-treated cotton fabric, and six moppings of asphalt.
Type F. Four layers of pitch-treated felt, one middle layer of pitch-treated cotton fabric, and six moppings of coal-tar pitch.

At places requiring greater strength, additional layers of bitumen-treated cotton fabric shall be applied.

Other types may be used at the discretion of the Engineer, but the mopped-on material shall be the same as that with which the felt or fabric is treated.

The first mopping of bitumen shall be placed on the surface to be waterproofed and shall be followed by alternate layers of fabric or felt and moppings of bitumen, ending with a mopping of bitumen on top.

(IV) MATERIALS

(1) Asphalt

Asphalt for Mopping and Saturant

4. Asphalt for mopping and saturant shall be homogeneous and free from water. It shall be the product obtained by the distillation of crude

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*Adopted, Vol. 28, 1927, pp. 718, 1338.

asphaltic base petroleum refined by direct heat without the addition of fluxing or other material during any stage of the process of manufacture. It shall meet the following requirements:*

(a) Softening point (ring and ball method) 150° to 170° Fahr. (65.5° to 76.7° C.)
(b) Penetration:
  at 115° Fahr. (46.1° C.), 50 g., 5 sec..not more than 100.
  at 77° Fahr. (25° C.), 100 g., 5 sec....25 to 40.
  at 32° Fahr. (0° C.), 200 g., 60 sec....not less than 10.
(c) Flash point (open cup)..not less than 400° Fahr. (204.4° C.)
(d) Loss on heating at 325° Fahr. (163° C.), 50 g., 5 hr. ....not more than 0.5 per cent.
(e) Penetration at 77° Fahr. (25° C.), 100 g., 5 sec. of residue after heating at 325° Fahr. (163° C.), as compared with penetration of asphalt before heating ....not less than 80 per cent.
(f) Ductility:
  at 77° Fahr. (25° C.)............not less than 20 cm.
(g) Solubility in carbon disulphide......not less than 99 per cent.

Asphalt for Mastic

5. Asphalt for mastic shall be homogeneous and free from water. It shall meet the following requirements:†

(a) Penetration:
  at 77° Fahr. (25°C.), 100 g., 5 sec..........25 to 30.
(b) Flash point (open cup)....not less than 347° Fahr. (175° C.)
(c) Loss on heating at 325° Fahr. (163° C.) 50 g., 5 hr......................... not more than 2 per cent.
(d) Penetration at 77° Fahr. (25° C.), 100 g., 5 sec. of residue after heating at 325° Fahr. (163° C.), as compared with penetration of asphalt before heating...not less than 60 per cent.
(e) Ductility at 77° Fahr. (25° C.)....not less than 15 cm.
(f) Solubility in carbon tetrachloride....not less than 99 per cent.

Note. When less than 99 per cent of asphalt is soluble in carbon tetrachloride, the percentage of bitumen (solubility in carbon disulphide) shall be reported.

(2) COAL-TAR PITCH

6. Coal-tar pitch shall be homogeneous and free from water. It shall meet the following requirements: ‡

(a) Specific Gravity at 77°/77° Fahr. (25°/25°C.)...1.25 to 1.35.
(b) Softening point (cube in water method)...................................130° to 155° Fahr. (54.4° to 68.3° C.)
(c) Distillation Test:
  Total distillate by weight 32° to 572° Fahr. (0 to 300° C.)...........................not more than 10 per cent.
  Residue by weight............not less than 90 per cent.
(d) Specific gravity, at 100°/77° Fahr. (38°/25° C.), of total distillate to 572° Fahr. (300° C.)......not less than 1.03.
(e) Ductility at 77° Fahr. (25° C.)..........not less than 20 cm.
(f) Solubility in carbon disulphide............63 to 78 per cent.

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*Same as A.S.T.M. Standards, Serial Designation D 144-25, except as follows:
(b) Penetration at 77° Fahr. 25 to 40 instead of 25 to 50.
(d) Loss on heating 0.5 per cent instead of 1.0 per cent.
(e) Penetration of residue after heating, 80 per cent instead of 60 per cent.
(f) Ductility 20 cm. instead of 15 cm.

†Same as A.S.T.M. Standards, Serial Designation D 163-23 T.

‡Same as A.S.T.M. Standards, Serial Designation D 145-25.

(3) ELASTIC CEMENT

7. Elastic cement shall be an asphalt homogeneous and free from water. It shall meet the following requirements:

(a) Softening point (ring and ball method............................120° to 130° Fahr. (48.8° to 54.4° C.)
(b) Penetration:
    at 115° Fahr. (46.1° C.), 50 g., 5 sec..not more than 300.
    at 77° Fahr. (25° C.), 100 g., 5 sec..........50 to 60.
    at 32° Fahr. (0° C.), 200 g., 60 sec....not less than 15.
(c) Loss on heating at 325° Fahr. (163° C.), 50 g., 5 hr.....................................not more than 0.5 per cent.
(d) Ductility at 77° Fahr. (25° C.)..........not less than 85.

The cement shall be of such a quality that it will form a complete and permanent bond with the adjacent materials. The volume shall not be reduced on exposure to weather, except by change of temperature.

(4) FABRIC*

8. Treated fabric shall be woven cotton cloth saturated with either asphalt or coal-tar pitch, as specified by the Engineer.

9. In the process of manufacture, the dry cotton fabric shall be treated thoroughly and uniformly at a temperature and speed that will not injure the fabric. This shall be accomplished by passing the fabric through the saturant and then calendering it in the presence of heat, after which it shall be cooled and wound into rolls.

10. The treated cotton fabric shall meet the following requirements:

(a) Width............not less than 30 nor more than 38 inches.
(b) Gross weight of roll....not less than 35 nor more than 80 lb.
(c) Average net weight per square yard...not less than 11 ounces.
(d) Moisture content based on net weight...not more than one per cent.
(e) Average strength at 70° Fahr. (21.1° C.), measured both in the direction of the warp and of the filling.......................................not less than 50 lb. per inch of width.
(f) Pliability at 32° Fahr. (0° C.)............not less than 10.
(g) Average loss on heating asphalt treated fabric (exclusive of moisture)..........................not more than 4 per cent.
(h) Weight of saturant....not less than one and three-fourths times the weight of the moisture-free untreated fabric in the same area.

11. The desaturated cotton fabric shall be wholly of cotton, and shall meet the following requirements:

(a) Average dry weight per square yard....not less than 4 ounces.
(b) Ash, based on dry weight of fabric..not more than one per cent.
(c) Thread count per inch both in the direction of the warp and of the filling..........not less than 18 nor more than 32.

12. Bitumen used in treating fabric shall be either asphalt meeting the requirements of Section 14, or coal-tar pitch meeting the requirements of Section 16, as required. It shall be liquified by heat alone and not by oils, petroleum, or other solvents.

13. The meshes of the fabric shall not be completely closed by the process of saturation. There shall be sufficient porosity to allow the mopped-on bitumen to pass through.

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*Conforms closely to A.S.T.M. Standards, Serial Designation D 173-25.

14. The width of the selvage shall be not more than $\frac{3}{16}$ inch.

15. The surface of the fabric shall not be coated or covered with talc or other substance which might interfere with the adhesion between the fabric and the mopped-on bitumen.

16. The finished fabric shall be free from visible defects, such as ragged or untrue edges, breaks, rents, and cracks. The surface shall be smooth and free from folds, knots, and excess bitumen.

17. The finished fabric shall be of such a quality that it may be unwound from the roll easily and without injury from sticking at atmospheric temperatures above 50° Fahr.

18. The finished fabric shall be wound on cylindrical mandrels not less than two inches in diameter, extending two to four inches beyond the ends of rolls. The rolls shall be securely tied or wrapped to prevent unrolling in transit.

(5) Felt*

19. Felt shall be rag-felt saturated, but not coated, with either asphalt or coal-tar pitch; or asbestos felt saturated, but not coated, with asphalt, as specified by the Engineer. The saturation shall be accomplished by passing the dry felt in single thickness through the saturant at a temperature and speed that will not injure the felt, and then calendaring it between heated cylinders. It shall then be cooled and wound into rolls.

20. The finished felt shall be of such quality that it may be unwound from the roll easily and without injury from cracking or sticking, at atmospheric temperatures above 50° Fahr.

21. The surface of the felt shall not be coated or covered with talc or other substance that might prevent the adhesion between the felt and the mopped-on bitumen.

22. The finished felt shall be free from visible defects, such as holes, ragged or untrue edges, breaks, tears, cracks, lumps, and indentations. The surface of the felt shall be uniformly smooth, and upon splitting or tearing on the bias or otherwise, shall appear reasonably free from the following defects:

(a) Lumps of underbeaten stock (that is, stock which has not been beaten or shredded into fiber in the process of manufacture).
(b) Foreign substances, such as fragments of stone, metal, leather, rubber, straw, wood, etc.
(c) Patches of unabsorbed saturant.
(d) Dry spots.

23. The felt shall be saturated thoroughly and uniformly. Two-inch strips, cut at random across the entire width and split open for their full length, shall show no unsaturated spots.

24. The rolls of felt shall be wrapped securely in strong paper of the same width as the felt. The wrapper shall be pasted at the overlap to prevent shifting.

25. The rag felt shall be made by felting vegetable and animal fibers.

26. The treated rag felt shall meet the following requirements:

(a) Width..32 or 36 inches with an allowable variation of ¼ inch.
(b) Gross weight of roll....not less than 50 nor more than 80 lb.

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*Conforms closely to A.S.T.M. Standards, Serial Designation D 172-23 T.

(c) Average net weight of 100 square feet............................14 pounds with an allowable variation of 8 per cent.

(d) Detached comminuted surfacing on 100 square feet..not more than one pound.

(e) Maximum deviation from average thickness after removal of the detached surfacing............not more than 15 per cent.

(f) Moisture content based on net weight...not more than 1 per cent.

(g) Average strength at 70° Fahr. with the fiber grain.........................not less than 25 pounds per inch of width.

(h) Average strength at 70° Fahr. across the fiber grain.........................not less than 15 pounds per inch of width.

(i) Pliability at 77° Fahr........................greater than 8.

(j) Average loss on heating asphalt treated felt (exclusive of moisture)..........................not more than 4 per cent.

(k) Weight of saturant.................................not less than 1.4 times the weight of the moisture-free untreated felt.

27. The desaturated rag felt shall meet the following requirements:

(a) Average "Number" (expressed on the basis of pounds per 480 square feet)..28, with an allowable deviation of 10 per cent.

(b) Ash based on the dry weight of the felt..not more than 8 per cent.

(c) Composition of the felt, based on a microscopic count of the fibers:

Cotton and wool fibers........not less than 75 per cent.
Jute and manila fibers......not more than 15 per cent.
Mechanical wood, etc., fibers..not more than 5 per cent.
Chemical wood fibers........not more than 5 per cent.

28. The asphalt saturated asbestos felt shall meet the following requirements:

(a) Width..32 or 36 inches with an allowable variation of ¼ inch.

(b) Gross weight of roll..not less than 40 nor more than 80 pounds.

(c) Net weight of 100 square feet ....20 pounds plus or minus 1.5 pounds.

(d) Moisture content based on net weight..not more than 0.5 per cent.

(e) Weight of saturant.. not less than 60 per cent of the weight of moisture-free felt.

(f) Loss on heating at 221° Fahr. (105° C.) for five hours...................................not more than 4 per cent.

(g) Average strength at 70° Fahr. (21° C.) across the fiber grain..........not less than 30 pounds per inch of width.

(h) Average strength at 70° Fahr. (21° C.) with the fiber grain...........not less than 60 pounds per inch of width.

29. The desaturated asbestos felt shall meet the following requirements:

(a) Average thickness................not less than 0.045 inches.

(b) The relative proportion of the organic and asbestos fibers based on a microscopic count shall be:

Organic............................not more than 10.
Asbestos...........................not less than 90.

(6) Brick

30. Brick for the protection course shall be dense, hard burned, uniform in size and quality, free from warp and have square corners. The

absorption of moisture by bricks immersed in water seven hours shall not exceed 10 per cent. of the weight of the dry brick.

(7) CONCRETE

31. The materials used in the concrete protection course shall meet the requirements of the current specifications for concrete, of the American Railway Engineering Association.

(8) ASPHALTIC PRIMER

32. Asphaltic primer shall be composed of asphalt and a solvent. The asphalt shall meet the requirements for asphalt in Section 14. The solvent shall be a hydro carbon distillate having an end point, on distillation, not above 500° Fahr. (260° C.). Not more than 20 per cent shall distill under 248° Fahr. (120° C.).

33. The primer shall be free from water and shall meet the following requirements:

(a) Sediment........................not more than one per cent.
(b) Asphaltic base, by weight..................25 to 35 per cent.

(9) ASPHALT MASTIC

34. Asphalt mastic shall be either premoulded blocks or poured-in-place mastic.

Poured-in-place mastic shall be composed of (a) asphalt mixed with mineral aggregates, or (b) mastic cake mixed with asphalt and mineral aggregates.

Asphalt

35. Asphalt for mastic shall meet the requirements of Section 15.

Coarse Mineral Aggregate

36. Coarse mineral aggregate shall be well graded crushed stone or washed gravel, that will pass a ⅜ inch screen and be retained on a No. 10 screen. It shall be free from soft particles and organic matter.

Fine Mineral Aggregate

37. Fine mineral aggregate shall be well graded washed sand or crushed stone, that will pass a No. 10 screen. It shall be free from soft particles and organic matter.

Mineral Filler

38. Mineral filler shall be finely ground limestone or silica meeting the following requirements:

(a) Passing a 200 mesh sieve..........not less than 50 per cent.
(b) Passing a 30 mesh sieve..........not less than 90 per cent.

Portland Cement

39. Portland cement shall meet the requirements of the current specifications for Portland cement, of the American Railway Engineering Association.

Mastic Cake

40. Mastic cake shall contain from 14 to 18 per cent., by weight, of matter soluble in pure benzol.

The soluble matter shall be asphalt which will meet the requirements of Section 15.

The insoluble matter shall be granular mineral matter, which will meet the requirements of Sections 47, 48 and 49.

Pre-moulded Blocks

41. Pre-moulded blocks shall meet the following requirements:

(a) They shall be 4 inches wide, 8 inches long, and 1¼ inches thick. A deviation of ¼ inch in length or ⅛ inch in width or thickness either way from these dimensions, shall be cause for rejection.

(b) The blocks shall be formed in moulds, under a pressure of not less than 3300 pounds per square inch of surface. An absorption test shall be made on blocks dried for 24 hours at a temperature of 150° Fahr. (65.5° C.) and then immersed in water seven days. The absorption of moisture under this test shall not exceed 1 per cent of the weight of the block.

(10) REINFORCING MATERIAL FOR CONCRETE PROTECTION

42. Reinforcing material shall be steel wire netting with a mesh not less than two inches. The wire shall be not smaller than No. 14 gage.

(11) INSULATING PAPER

43. Insulating paper shall be a waterproof paper 36 inches wide and weighing not less than 10 lb. per 100 square feet.

(12) MARKING

44. Bituminous materials, fabric, and felt shall be delivered on the work in the original packages bearing the manufacturer's brand or label. The kind of saturant for the fabric and felt shall be indicated.

(13) INSPECTION AND TESTS

45. Material shall be sampled and tested for the specified properties by the current methods recommended by the American Society for Testing Materials.

46. Materials to be furnished by a Contractor shall be delivered on the work at least three weeks before they are to be applied, in order that they may be tested and analyzed. No work shall be begun until the materials have been accepted by the Engineer.

47. The bidder shall submit with his bid samples of the bitumen, fabric and felt that he proposes to furnish, accompanied by test reports as evidence that he is producing material of the quality specified. The tests covered by these reports shall meet every requirement of these specifications.

48. When materials are delivered on the work, the Engineer may take samples at random for tests. If the tests show that any material does not meet the specification requirements, the Contractor shall remove such material immediately from the work at his own expense.

(V) APPLICATION

(1) GENERAL

49. Waterproofing shall not be done in wet weather nor at a temperature below 50 degrees Fahr. without permission from the Engineer.

50. The work shall be done by competent workmen, skilled in the kinds of work specified.

(2) PREPARATION OF SURFACES

51. Surfaces of concrete and steel to be waterproofed shall be smooth and free from projections which might injure the waterproofing membrane. The surface shall be cleaned of dust, dirt, grease and loose particles. The use of hand bellows is recommended for removing dust and loose dirt from corners and joints. For removing grease from the steel, freshening the surface of the asphalt where a joining of old and new is to be made, or where elastic cement is to be applied against the steel and the membrane or the protection course, gasoline shall be used. The gasoline may be applied by swabbing or by pouring on a small quantity and setting fire to it. A blow torch also may be used. The surface shall be clean and dry when the waterproofing is applied. Damp surfaces may be dried by covering with a layer of hot sand. The sand shall remain in place one or two hours, after which it shall be removed from enough surface to allow the work to proceed. Another method is to swab with gasoline and set fire to it.

(3) PRIMING COAT

52. If specified by the Engineer, surfaces of concrete or steel coming in contact with asphalt waterproofing shall be given one coat of asphaltic primer. The primer shall be thoroughly worked in to give a uniform coating.

53. Priming shall be done immediately before applying the waterproofing membrane. The priming coat shall be dry before the membrane is applied.

(4) FLOATING MEMBRANE

54. If bond between the membrane and the surface to be waterproofed is not desired, the surface shall be covered with insulating paper meeting the requirements of Section 53.

(5) WORKMANSHIP

55. The felt or fabric shall be laid single fashion with the specified number of layers, and with the top layer lapped two inches over the bottom layer. Each strip shall be laid in a mopping of hot bitumen and, when the specified number of layers has been laid, the entire surface shall be mopped. If practicable, the laying of the felt or fabric shall be begun at the lowest part of the surface to be waterproofed. The surface shall be completely covered with a heavy mopping of bitumen before the strip of felt or fabric is put down. The mopping shall be so done that there will be no air bubbles or pockets, or spots where the surface shows through. If fabric is used, this mopping of bitumen shall be sufficient to fill the open meshes in the fabric when it is pressed down. As soon as a strip of felt or fabric has been laid, it shall be pressed into the hot bitumen to eliminate the air bubbles. Creases in the fabric shall be smoothed out carefully by pulling the fabric. The top mopping shall be of such thickness and be so applied as to seal and cover the fabric or felt completely.

56. Special care shall be taken that the felt or fabric is completely sealed down at the laps. The waterproofing membrane shall be continuous and unbroken. The work shall be so regulated that at the end of the day,

the fabric or felt that has been laid will have received the final mopping of bitumen. At joints in the membrane, the laps shall be at least 12 inches. The felt or fabric for making the lap shall be left unmopped until the joint is to be completed.

57. The amount of bitumen in each mopping of 100 square feet of surface shall be not less than 4½ gallons.

58. Care shall be taken to avoid overheating the bitumen. The temperature of the bitumen in the kettle shall not be above 350° Fahr., and not below 250° Fahr., just before the bitumen is placed in the work. Kettles shall be equipped with thermometers.

59. Special care shall be taken to make the waterproofing effective along the sides and at the ends of girders, and at stiffeners, gussets, etc.

The waterproofing membrane shall be turned down into the drainage casting without a break.

60. Waterproofing shall be protected against mechanical injury, high temperature, and chemical action, as soon as possible after completion.

(6) Concrete Protection Course

61. The concrete protection course shall be not less than one and one-half inches thick, and reinforced as required by the plans. The concrete shall be 1-2-4 mixture of a consistency as dry as is workable. The size of the coarse aggregate shall not exceed ½ inch. The top surface of the concrete shall be true to grade and troweled to a smooth finish.

62. Unless approved by the Engineer, trains shall not be allowed over waterproofed surfaces until the concrete deposited last has had the equivalent of seven days of good curing weather.

(7) Brick Protection Course

63. The brick protection course shall be laid over the entire membrane, except around the drainage castings and other places shown on the plans. In such places concrete shall be used.

64. The laying of brick shall follow the waterproofing closely, and the joints shall be filled immediately. Unless otherwise specified, the joints shall be filled with bitumen of the kind used for the waterproofing. The bricks shall be dry when the joints are filled.

(8) Asphalt Mastic Protection Course

Pre-moulded Blocks

65. The pre-moulded block protection course shall be laid over the entire membrane, except around the drainage castings and other places shown on the plans. In such places poured-in-place mastic or concrete shall be used.

66. The laying of the blocks shall follow the waterproofing closely. The blocks shall be laid in hot asphalt and the joints shall be filled immediately with asphalt. The asphalt shall meet the requirements of Section 15.

Poured-in-Place Mastic

67. The poured-in-place mastic protection course shall be not less than one and one-half inches thick, and shall be laid on one thickness of insulating paper on the membrane. The insulating paper shall meet the requirements of Section 53.

68. Asphalt and mineral aggregates shall be mixed in the following proportions:

Asphalt	9 to 12 per cent.
Coarse mineral aggregate	35 to 40 per cent.
Fine mineral aggregate	33 to 37 per cent.
Portland cement or mineral filler	15 to 19 per cent.

The proportions should be varied to give a mastic of the greatest density and stability.

69. Mastic cake, asphalt, and mineral aggregates shall be mixed in about the following proportions:

Mastic cake	48 per cent.
Asphalt	5 per cent.
Fine mineral aggregate and cement or mineral filler	19 per cent.
Coarse mineral aggregate	28 per cent.

The proportions should be varied to give a mastic of the greatest density and stability.

70. The asphalt and the mastic cake shall be heated to 350° Fahr. The aggregates shall be mixed and heated, and placed in the melted asphalt in the kettle. The ingredients shall be mixed thoroughly with iron stirring rods until all particles of the aggregates are covered with and incorporated in the asphalt, care being taken to prevent burning. After the mastic is mixed it shall be removed from the kettle and poured while hot. It shall be placed in layers not more than ¾ inch thick, the thickness of the layers being gaged by wooden strips held in position by suitable weights. The layers shall lap not less than six inches at the joints and shall be brought to the required thickness with wooden spreaders and floats. The top layer shall be finished to the required grade and with a smooth surface. On surfaces steeper than 4½ vertical to 12 horizontal, brick or concrete protection shall be used instead of mastic. As soon as the top layer of the mastic is finished, it shall be given a mopping of hot asphalt sanded to a walking surface while hot.

[7]SPECIFICATIONS FOR STEEL HIGHWAY BRIDGES—1929

FOREWORD

Compiled by a Conference Committee composed of representatives from the American Association of State Highway Officials and the American Railway Engineering Association.

In scope these specifications are limited to the field of ordinary highway bridges and do not provide for unusual span lengths and types of construction for which provision must be made by special supplemental specifications.

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[7] Adopted, Vol. 30, 1929, pp. 955, 1452.

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(I) GENERAL REQUIREMENTS AND BASIS OF PAYMENT

Definitions of Terms

101. The term "Purchaser" means the individual, company, or public authority contracting for the construction of a bridge under these specifications.

The term "Contractor" means the individual, partnership, or corporation contracting to construct a bridge under these specifications.

The term "Engineer" means the engineer representing the Purchaser. The Engineer may act directly or through an authorized representative.

The term "Inspector" means the inspector authorized to represent the Engineer.

Proposals

102. Proposals preferably shall be based on plans and specifications furnished by the Purchaser. If the bridge is to be designed or erected by the Contractor, the invitation to bidders shall give information as to conditions at the site.

Drawings

103. Before any work is begun under the contract, the Contractor shall submit to the Engineer for approval, prints of stress sheets and shop drawings, unless such drawings have been prepared by the Purchaser. These prints shall be in duplicate unless more are specified. Tracings of these drawings, in ink on tracing cloth, shall, if required, be delivered to the Engineer upon completion of the work and be the property of the Purchaser.

104. Changes on approved drawings shall be subject to the approval of the Engineer, and he shall be supplied with a record of such changes.

105. Substitutions of sections different from those shown on the drawings shall be made only when approved in writing by the Engineer.

106. The Contractor shall be responsible for the correctness of his drawings, and for shop fits and field connections, although the drawings may have been approved by the Engineer.

107. Any material ordered or work done by the Contractor before the drawings have been approved, shall be at his risk.

108. If the drawings and specifications differ, the drawings shall govern.

Patented Devices

109. The Contractor shall protect the Purchaser against claims on account of patented devices or parts used by the Contractor unless such use has been specified by the Purchaser.

Basis of Payment

110. The contract price for fabrication and erection of structural steel shall include all labor, materials, transportation, and shop and field painting necessary for the proper completion of the work in accordance with the contract.

The contract price for fabrication without erection shall include all labor and materials necessary for fabrication, shop painting, shipping and delivery at the place designated.

Payment will be made on a pound-price or a lump-sum basis, as required by the terms of the contract. For the purpose of payment, such items as bearing plates, pedestals, etc., shall, unless otherwise provided, be considered as structural steel even though made of other materials.

Payment for Test Eye-Bars

111. Full-size eye-bars which are tested and meet the requirements of these specifications shall be paid for by the Purchaser at the same rate as for the structure. Bars which fail to meet these requirements, and all bars rejected as a result of tests, shall not be paid for by the Purchaser.

Pay Weight

112. The payment in pound-price contracts shall be based on the weight of metal in the fabricated structure, including field rivets shipped. The weight of erection bolts, field paint, boxes, crates, and other containers used for packing, and materials used for supporting members during transportation, shall not be included.

Any weight in excess of 1½ per cent above the computed weight shall not be included in the pay weight.

The weight paid for shall be the shop scale weight unless otherwise provided. If specified in the contract or permitted by the Engineer, computed weights, obtained as hereinafter described, may be made the basis of payment.

Variance in Weight

113. If the scale weight of any member is less than 97½ per cent of the computed weight, the member may be rejected. This applies to both pound-price and lump-sum contracts.

Computed Weight

114. The computed weight shall be obtained by the use of the following rules and assumptions:

(a) The weight of steel shall be assumed at 0.2833 lb. per cubic inch. The weight of cast iron shall be assumed at 0.26 lb. per cubic inch. The weight of bronze shall be assumed at 0.315 lb. per cubic inch.

(b) The weights of rolled shapes, and of plates up to and including 36 inches in width, shall be computed on the basis of their nominal weights and dimensions, as shown on the approved shop drawings, deducting for copes, cuts, and open holes.

To the nominal weights of plates more than 36 inches in width, there shall be added one-half of the allowed percentage of overrun in weight given in the Specifications for Structural Steel, described in Article 201.

(c) The weight of heads of shop-driven rivets shall be included in the computed weight, assuming the weights to be as follows:

Diameter of rivet	*Weight of 100 heads, pounds*
½ inch	4.0
⅝ inch	7.5
¾ inch	12.5
⅞ inch	18.5
1 inch	27.0

(d) The weight of castings shall be computed from the dimensions shown on the approved shop drawings, with an addition of 10 per cent for fillets and overrun.

(e) To the total computed weight of metal may be added 0.4 of one per cent as an allowance for shop paint.

(II) MATERIALS

Structural and Rivet Steel

201. Structural and rivet steel shall conform to the requirements of the Standard Specifications for Structural Steel for Bridges, Serial Designation A7-24, of the American Society for Testing Materials, with revisions thereof adopted by that Society.

Steel Castings

202. Steel castings shall conform to the requirements of the Standard Specifications for Steel Castings, Serial Designation A-27-24, of the American Society for Testing Materials, with revisions thereof adopted by that Society, except that steel produced by the converter process shall not be used.

Castings shall be Class B, Medium Grade.

Gray-Iron Castings

203. Gray-iron castings shall conform to the requirements of the Standard Specifications for Gray-Iron Castings, Serial Designation A-48-18, of the American Society for Testing Materials, with revisions thereof adopted by that Society.

Malleable Castings

204. Malleable castings shall conform to the requirements of the Standard Specifications for Malleable Castings, Serial Designation A-47-27, of the American Society for Testing Materials, with revisions thereof adopted by that Society.

Phosphor-Bronze

205. Phosphor-bronze shall conform to the requirements of the Standard Specifications for Bronze Bearing Metals for Turntables and Movable Railroad Bridges, Serial Designation B-22-21, of the American Society for Testing Materials, with revisions thereof adopted by that Society.

Grade B metal shall be used.

(III) WORKMANSHIP

Quality of Workmanship

301. Workmanship and finish shall be equal to the best general practice in modern bridge shops.

Storage of Materials

302. Structural material, either plain or fabricated, shall be stored at the bridge shop above the ground upon platforms, skids, or other supports. It shall be kept free from dirt, grease and other foreign matter, and shall be protected as far as practicable from corrosion.

Straightening Material

303. Rolled material before being laid off or worked, must be straight. If straightening is necessary, it shall be done by methods that will not injure the metal. Sharp kinks and bends may be cause for rejection of the material.

Finish

304. Portions of the work exposed to view shall be finished neatly. Shearing and chipping shall be done carefully and accurately.

Punched Work

305. If general reaming is not required, all main material, forming parts of a member composed of not more than 5 thicknesses of metal, may be punched with a punch 1/16 in. larger than the nominal size of the rivets, whenever the thickness of the metal is not greater than ¾ in. When there are more than 5 thicknesses, or when any of the main material is thicker than ¾ in., all of the holes shall be punched with a punch 3/16 in. smaller, and after assembling reamed 1/16 in. larger than the nominal size of the rivets, except that when the metal is thicker than the size of the rivet, the holes shall be drilled.

Punched Holes

306. Holes punched full-size shall be 1/16 inch larger than the nominal diameter of the rivet. The diameter of the die shall not exceed the diameter of the punch by more than 3/32 inch. Holes shall be clean cut and without torn or ragged edges.

Accuracy of Punched Holes

307. The punching of holes shall be done so accurately that, after assembling the component parts of a member, a cylindrical pin ⅛ inch smaller than the nominal diameter of the punched hole may be passed through at least 75 of any group of 100 contiguous holes, or in like proportion for any smaller group of holes. If this requirement is not fulfilled, the badly punched pieces may be rejected. If 10 per cent of any group of 100 or fewer holes will not pass a pin 3/16 inch smaller than the nominal diameter of the punched hole, the mispunched pieces may be rejected.

Reamed Work

308. General reaming will be required if provided for in the contract.

If general reaming is required, holes shall be sub-punched and reamed in material forming a part of the section of main members if the thickness of the material is not greater than the nominal diameter of the rivet. Holes may be punched full size in material used for lateral, longitudinal, and sway bracing, lacing bars, stay plates, and diaphragms, not forming a part of the section of main members if the thickness of the material is not greater than the nominal diameter of the rivet. Holes shall be drilled in material, the thickness of which is greater than the nominal diameter of the rivet.

Sub-Punched Holes

309. Sub-punched and reamed holes for rivets having diameters greater than ¾ inch shall be punched 3/16 inch smaller than the nominal diameter of the rivet. For rivets having diameters of ¾ inch, the holes shall be punched 11/16 inch in diameter. For rivets having diameters of ⅝ inch or less, the holes shall be punched full size and spear-reamed. The punch and die shall have the same relative sizes as specified for full size punched holes.

Reaming

310. After assembling, sub-punched holes shall be reamed to a diameter 1/16 inch larger than the nominal diameter of the rivet.

Reaming shall be done after the pieces forming a built member are assembled and firmly bolted together. Reamed parts shall not be interchanged.

Reaming of rivet holes shall be done with twist drills or with short taper reamers. Reamers preferably shall not be directed by hand. If oil or grease is used as a lubricant when reaming, it shall be applied so as not to soil surfaces which are to be painted. Burrs resulting from reaming shall be removed.

Drilled Holes

311. Drilled holes shall be 1/16 inch larger than the nominal diameter of the rivet. Burrs on the outside surfaces shall be removed. If members are drilled while assembled, the parts shall be held securely together while the drilling is being done.

Accuracy of Reamed and Drilled Holes

312. Reamed or drilled holes shall be cylindrical and perpendicular to the member. After reaming or drilling, 85 of any group of 100 contiguous holes, or in like proportion for any smaller group of holes, shall not show an offset greater than 1/32 inch between adjacent thicknesses of metal.

Shop Assembling

313. Surfaces of metal in contact shall be cleaned before assembling.

The parts of a member shall be assembled, well pinned, and firmly drawn together with bolts before reaming or riveting is commenced. Assembled pieces shall be taken apart, if necessary, for the removal of burrs and shavings produced by the reaming operation. The member shall be free from twists, bends, and other deformation.

Preparatory to the shop riveting of material punched full size, the rivet holes, if necessary, shall be spear-reamed for the admission of the rivets. The reamed holes shall not be more than 3/32 inch larger than the nominal diameter of the rivets.

End connection angles, stiffener angles, and similar parts shall be carefully adjusted to correct position and bolted, clamped, or otherwise firmly held in place until riveted.

Parts not completely riveted in the shop shall be secured by bolts in so far as practicable to prevent damage in shipment and handling.

Drifting of Holes

314. The drifting done during assembling shall be only such as to bring the parts into position, and not sufficient to enlarge the holes or distort the metal. If any holes must be enlarged to admit the rivets, they shall be reamed.

Reaming of Field Connections

315. If general reaming is required, riveted trusses and skew portals shall be assembled in the shop, the parts adjusted to line and fit, and holes for field connections drilled or reamed while so assembled. Holes for other field connections, except those in lateral, longitudinal, and sway bracing, shall be drilled or reamed in the shop with the connecting parts assembled, or else drilled or reamed to a metal template without assembling.

If provided in the contract, the field connections in punched work, except those for lateral, longitudinal and sway bracing, shall be reamed to a metal template or else with the parts assembled.

Match-Marking

316. Connecting parts assembled in the shop for the purpose of reaming holes in field connections shall be match marked, and a diagram showing such marks shall be furnished to the Engineer.

Rivets

317. Rivets before driving shall be of the diameter specified. They shall be free from furnace scale.

Rivet heads shall be of approved shape, concentric with the shank, true to size, full, neatly formed, and free from fins.

Field Rivets

318. Field rivets shall be furnished in excess of the nominal number required to the amount of 10 per cent plus 10 rivets for each diameter and length.

Field Bolts

319. Bolted connections shall not be used unless specifically authorized. If bolted connections are permitted, the bolts shall be unfinished bolts or turned bolts, as specified. Bolts shall have hexagonal heads and nuts and shall be of such length that they will extend entirely through the nut but not more than ¼ inch beyond. Bolts in tension shall have two nuts.

Unfinished bolts in shear shall have not more than one thread within the grip. The diameter of the unfinished bolt shall not be more than $\frac{1}{16}$ inch smaller than the diameter of the hole.

The threads of turned bolts shall be entirely outside the grip. The bolts shall be given a finishing cut. Approved nut locks or flat washers ¼ inch thick shall be furnished, as specified. The holes for turned bolts shall be reamed and their diameters shall be not more than $\frac{1}{32}$ inch greater than the diameter of the finished bolt.

Riveting

320. Rivets shall be heated uniformly to a light cherry-red color and shall be driven while hot. Rivets, when heated and ready for driving, shall

be free from slag, scale, and other adhering matter. When driven, they shall completely fill the holes. The heads shall be of approved shape, full size, neatly formed, concentric with the shank, free from fins, and in full contact with the surface of the member.

Loose, burned or otherwise defective rivets shall be replaced. In removing rivets, care shall be taken not to injure the adjacent metal, and, if necessary, they shall be drilled out. Caulking or recupping will not be permitted.

Rivets shall be driven by direct-acting riveters where practicable. The riveters shall retain the pressure after the upsetting is completed. If rivets are driven with a pneumatic hammer, a pneumatic bucker shall be used if practicable.

Edge Planing

321. Sheared edges of plates more than ⅝ inch in thickness and carrying calculated stress shall be planed to a depth of ¼ inch. Reentrant cuts shall be filleted before cutting.

Facing of Bearing Surfaces

322. The top and bottom surfaces of steel slabs and base plates and cap plates of columns and pedestals shall be planed, or else the plates or slabs hot straightened. Parts of members in contact with them shall be faced.

Sole plates of beams and girders shall have full contact with the flanges. Sole plates and masonry plates shall be planed or hot straightened. Cast pedestals shall be planed on surfaces to be in contact with steel and shall have the surface to be in contact with masonry, rough finished.

Surfaces of bronze bearing plates intended for sliding contact, shall be finished.

In planing the surfaces of expansion bearings the cut of the tool shall be in the direction of expansion.

Abutting Joints

323. Abutting joints in compression members and girder flanges, and, in tension members where so specified on the drawings, shall be faced and brought to an even bearing. Where joints are not faced, the opening shall not exceed ¼ inch.

End Connection Angles

324. Floor beams, stringers, and girders having end connection angles shall be built to exact length back to back of connection angles. If end connections are faced, the finished thickness of the angles shall be not less than that shown on the detail drawings.

Lacing Bars

325. The ends of lacing bars shall be neatly rounded unless another form is required.

Finished Members

326. Finished members shall be true to line and free from twists, bends, and open joints.

Web Plates

327. In girders having no cover plates and not to be encased in concrete, the top edge of the web plate shall not extend above the backs of the flange angles, and shall not be more than ⅛ in. below at any point. Any portion of the plate projecting beyond the angles shall be chipped flush with the backs of the angles. Web plates of girders having cover plates may be ½ inch less in width than the distance back-to-back of flange angles.

At web splices, the clearance between the ends of the web plates shall not exceed ⅜ inch. The clearance at the top and bottom ends of web splice plates shall not exceed ¼ inch.

Fit of Stiffeners

328. End stiffener angles of girders and stiffener angles intended as supports for concentrated loads shall be milled or ground to secure an even bearing against the flange angles. Intermediate stiffener angles shall fit sufficiently tight to exclude water after being painted. Fillers under stiffeners shall fit within ¼ inch at each end.

Eye-Bars

329. Eye-bars shall be straight, true to size, and free from twists, folds in the neck and head, and other defects. The heads shall be made by upsetting and rolling or forging, and not by welding. The form of the heads will be determined by the dies in use at the works where the eye-bars are made, if they are satisfactory to the Engineer. The thickness of the head and neck shall not overrun more than $\frac{1}{16}$ in.

Eye-bars that are to be placed side by side in the structure shall be bored so accurately that upon being placed together, pins $\frac{1}{32}$ in. less in diameter than the pin holes will pass through the holes at both ends at the same time without driving.

Annealing

330. Before boring, eye-bars shall be annealed to produce the required physical qualities and shall be straightened. Proper instruments shall be provided for determining at any time the temperature of the bars.

Other steel that has been heated partially shall be annealed, unless it is to be used in minor parts. Crimped stiffeners need not be annealed.

Pins and Rollers

331. Pins and rollers shall be accurately turned to the dimensions shown on the drawings and shall be straight, smooth, and free from flaws. The final surface shall be produced by a finishing cut.

Pins more than 7 inches in diameter shall be forged and annealed.

In pins larger than 9 inches in diameter, a hole not less than 2 inches in diameter shall be bored full length along the axis.

Boring Pin Holes

332. Pin holes shall be bored true to the specified diameter, smooth and straight, at right angles with the axis of the member and parallel with each other unless otherwise required. The final surface shall be produced by a finishing cut.

The distance outside-to-outside of holes in tension members and inside-to-inside of holes in compression members shall not vary from that specified more than $\frac{1}{32}$ inch. Boring of holes in built up members shall be done after the riveting is completed.

Pin Clearances

333. The diameter of the pin hole shall not exceed that of the pin by more than 1/50 inch for pins 5 inches or less in diameter, or $\frac{1}{32}$ inch for larger pins.

Welds

334. Welding of steel shall not be done except to remedy minor defects and then only with the approval of the Engineer.

Screw Threads

335. Screw threads shall make close fits in the nuts and shall be U.S. Standard, except that for pin ends of diameters greater than 1½ inches, they shall be made with 6 threads to the inch.

Pilot and Driving Nuts

336. Two pilot nuts and two driving nuts for each size of pin shall be furnished, unless otherwise specified.

(IV) MILL AND SHOP INSPECTION

Notice of Beginning of Work

401. The Contractor shall give the Engineer ample notice of the beginning of work at the mill or in the shop, so that inspection may be provided. The term mill means any rolling mill or foundry where material for the work is to be manufactured. No material shall be manufactured or work done in the shop before the Engineer has been so notified.

Facilities for Inspection

402. The Contractor shall furnish facilities for the inspection of material and workmanship in the mill and shop, and the Inspectors shall be allowed free access to the necessary parts of the works.

Inspector's Authority

403. The Inspector shall have the authority to reject any material or work which does not meet the requirements of these specifications. In case of dispute the Contractor may appeal to the Engineer, whose decision shall be final.

Mill Orders and Shipping Statements

404. The Contractor shall furnish the Engineer with as many copies of mill orders and shipping statements as the Engineer may direct. The weights of the individual members shall be shown on the statements.

Facilities for Testing

405. The Contractor shall furnish test specimens, as specified herein, without extra charge; also the labor, testing machines and tools necessary to make the specimen and full size tests.

Rejections

406. The acceptance of any material or finished members by the Inspector shall not be a bar to their subsequent rejection, if found defective.

Rejected material and workmanship shall be replaced promptly or made good by the Contractor.

(V) FULL-SIZE TESTS OF EYE-BARS

Full-Size Tests

501. If tests of full-size eye-bars are required, they shall be made under the following conditions and requirements:

Number and Size of Test Bars

502. The number and size of the bars to be tested shall be stipulated by the Engineer before the mill order is placed. The number shall not exceed 5 per cent of the whole number of bars ordered, with a minimum of two bars.

Selection of Test Bars

503. The test bars shall be of the same section as the bars to be used in the structure and of the same length if within the capacity of the testing machine. They shall be selected by the Inspector from the finished bars. Test bars representing bars too long for the testing machine shall be selected from the full-length bar material after the heads on one end have been formed. Then they shall be cut and the second head formed, making a bar of the greatest length that can be tested.

Physical Requirements

504. Full-size tests of eye-bars shall show a yield point of not less than 33,000 pounds per square inch, an ultimate strength of not less than 60,000 pounds per square inch, and an elongation, including the fracture, of not less than 12 per cent in a length of 18 feet measured in the body of the bar. The fracture shall show a uniform silky or fine granular structure throughout.

Failure to Fulfill Requirements

505. If a bar fails to fulfill the specified requirements, two additional bars of the same size and from the same mill heat shall be tested. The bars represented by the test may be reannealed before the additional bars are tested.

If two of the three bars tested fail, the bars of that size and mill heat shall be rejected.

Record of Annealing

506. A record of the annealing furnace charges, showing the bars in each charge and the details of the treatment as to temperature and time, shall be furnished to the Engineer.

(VI) SHOP PAINTING

General Conditions

601. The painting of metal structures shall include, unless otherwise provided in the contract, the preparation of the metal surfaces, the application, protection, and drying of the paint coatings, and the supplying of all tools, tackle, scaffolding, labor, and materials necessary for the entire work.

Paint

602. The paint used shall be that specified or approved by the Engineer.

Mixing of Paint

603. Paint shall be thoroughly mixed before applying, and the pigments shall be kept in suspension.

Weather Conditions

604. Paint shall not be applied when the air temperature is below 40° Fahr., or when the air is misty, or when, in the opinion of the Engineer, conditions are otherwise unsatisfactory for the work. It shall not be applied upon damp or frosted surfaces.

Material painted under cover in damp or cold weather shall remain under cover until dry or until weather conditions permit its exposure in the open. Painting shall not be done when the metal is hot enough to cause the paint to blister and produce a porous paint film.

Application

605. Painting shall be done in a neat and workmanlike manner. Brushes preferably shall be round or oval in shape, but if flat brushes are used they shall not exceed 4 inches in width.

The paint when applied shall be so manipulated under the brush as to produce a uniform, even coating in close contact with the metal or with previously applied paint and shall be worked into all corners and crevices.

On surfaces which are inaccessible to paint brushes, the paint shall be applied with sheepskin daubers specially constructed for the purpose.

Removal of Paint

606. If the painting is unsatisfactory to the Engineer, the paint shall be removed and the metal thoroughly cleaned and repainted.

Thinning Paint

607. If it is necessary in cool weather to thin the paint on account of congealing, this shall be done only by heating.

Cleaning

608. Surfaces of metal to be painted shall be thoroughly cleaned, removing rust, loose mill scale, dirt, oil or grease, and other foreign substances. The removal of rust, scale, and dirt shall be done by the use of metal brushes, scrapers, chisels, hammers, or other effective means. Oil and grease shall be removed by the use of gasoline or benzine. Bristle brushes shall be used for removing loose dust.

Contact and Inaccessible Surfaces

609. Surfaces to be riveted in contact either in the shop or field shall not be painted. Surfaces not in contact but which will be inaccessible after assembly or erection shall be painted two coats.

Shop Painting

610. When fabrication is complete and the work has been accepted, surfaces not painted before assembling, except surfaces to be in contact after erection, shall be painted one coat. Material shall not be loaded for shipment until the paint is dry.

Erection Marks

611. Erection marks shall be painted on painted surfaces.

Machine-Finished Surfaces

612. With the exception of abutting chord and column splices and column and truss shoe bases, machine-finished surfaces shall be coated as soon as practicable after being accepted, and before removal from the shop, with a hot mixture of white lead and tallow. Surfaces of iron and steel castings machine-finished for the sole purpose of removing scales, scabs, fins, blisters, or other surface deformations shall be given the shop coat of paint.

The composition used for coating machine-finished surfaces shall be mixed in the following proportions: 4 pounds tallow, 2 pounds white lead, and 1 quart linseed oil.

(VII) WEIGHING, MARKING AND SHIPPING

Weighing of Members

701. Finished work shall be weighed in the presence of the Inspector, if practicable. The Contractor shall supply satisfactory scales and shall do the handling and weighing.

Marking and Shipping

702. Members weighing more than 3 tons shall have the weight marked thereon. Bolts and rivets of one length and diameter, and loose nuts or washers of each size, shall be packed separately. Pins, small parts, and small packages of bolts, rivets, washers, and nuts shall be shipped in boxes, crates, kegs, or barrels, but the gross weight of any package shall not exceed 300 lb. A list and description of the contained material shall be plainly marked on the outside of each package.

Anchor bolts, washers, and other anchorage or grillage materials, shall be shipped in time to suit the requirements of the masonry construction.

Handling Material

703. The loading, transportation, unloading, and storing of structural material shall be conducted so that the metal will be kept clean and free from injury.

(VIII) ERECTION

Masonry

801. If the substructure and superstructure are built under separate contracts, the Purchaser will provide the masonry, constructed to correct lines and elevations and properly finished, and will establish the lines and elevations required for setting the steel.

Plans

802. If the fabrication and erection of the superstructure are done under separate contracts, the Purchaser will furnish detail plans for the bridge or bridges to be erected, including shop details, camber diagrams, erection diagrams, list of field rivets and bolts, and copy of shipping statements showing a list of parts and their weights.

Work to be Done

803. The Contractor shall erect the metal work, remove the temporary construction, and do all work required to complete the bridge or bridges as covered by the agreement, including the removal of the old structure or structures, if stipulated, all in accordance with the plans and these specifications.

Plant

804. The Contractor shall provide the falsework and all tools, machinery, and appliances, including drift pins and fitting up bolts, necessary for the expeditious handling of the work. Temporary structures or falsework placed by the Purchaser, if suitable, may be used by the Contractor.

Delivery of Materials

805. If the contract is for erection only, the Contractor shall receive the materials entering into the finished structure, free of charge at the place designated and loaded or unloaded as specified. The Contractor shall unload promptly upon delivery any material delivered on railroad cars which he is required to unload; otherwise he shall be responsible for demurrage charges.

Handling and Storing Materials

806. Material to be stored shall be placed on skids above the ground. It shall be kept clean and properly drained. Girders and beams shall be placed upright and shored. Long members, such as columns and chords, shall be supported on skids placed near enough together to prevent injury from deflection. The Contractor shall check the material turned over to him against the shipping lists and report promptly in writing any shortage or injury discovered. He shall be responsible for the loss of any material while in his care, or for any damage resulting from his work.

Falsework

807. The falsework shall be properly designed and substantially constructed and maintained for the loads which will come upon it. The Contractor, if required, shall prepare and submit to the Engineer for approval, plans for falsework or for changes in an existing structure necessary for maintaining traffic. Approval of the Contractor's plans shall not be considered as relieving the Contractor of any responsibility.

Methods and Equipment

808. Before starting work, the Contractor shall inform the Engineer fully as to the method of erection he proposes to follow, and the amount and character of equipment he proposes to use, which shall be subject to the approval of the Engineer. The approval of the Engineer shall not be considered as relieving the Contractor of the responsibility for the safety of his method or equipment or from carrying out the work in full accordance with the plans and specifications. No work shall be done without the sanction of the Engineer.

Bearings and Anchorage

809. Masonry bearing plates shall not be placed upon bridge-seat bearing areas which are improperly finished, deformed or irregular. Bearing

plates shall be set level in exact position and shall have a full and even bearing upon the masonry. Unless otherwise directed by the Engineer, they shall be placed on a layer of canvas and red lead applied as follows:

Thoroughly swab the bridge seat bearing area with red lead paint and place upon it three layers of 12 to 14 ounce duck, each layer being thoroughly swabbed on its top surface with red lead paint. Place the superstructure shoes or pedestals in position while the paint is plastic.

The Contractor shall drill the holes and set the anchor bolts, except where the bolts are built into the masonry. The bolts shall be set accurately and fixed with Portland cement grout completely filling the holes. The location of the anchor bolts in relation to the slotted holes in the expansion shoes shall correspond with the temperature at the time of erection. The nuts on anchor bolts at the expansion ends of spans shall be adjusted to permit the free movement of the span.

Straightening Bent Material

810. The straightening of plates and angles or other shapes shall be done by methods not likely to produce fracture or other injury. The metal shall not be heated unless permitted by the Engineer, in which case the heating shall not be to a higher temperature than that producing a dark cherry red color. After heating the metal shall be cooled as slowly as possible.

Following the straightening of a bend or buckle, the surface of the metal shall be carefully inspected for evidence of fracture.

Assembling Steel

811. The parts shall be accurately assembled as shown on the plans and any match-marks shall be followed. The material shall be carefully handled so that no parts will be bent, broken, or otherwise damaged. Hammering which will injure or distort the members shall not be done. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled. Unless erected by the cantilever method, truss spans shall be erected on blocking so placed as to give the trusses proper camber. The blocking shall be left in place until the tension chord splices are fully riveted and all other truss connections pinned and bolted. Rivets in splices of butt joints of compression members and rivets in railings shall not be driven until the span has been swung. Splices and field connections shall have one-half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before riveting. Splices and connections carrying traffic during erection shall have three-fourths of the holes so filled.

Fitting up bolts shall be of the same nominal diameter as the rivets, and cylindrical erection pins shall be $\frac{1}{32}$ inch larger.

Riveting

812. Pneumatic hammers shall be used for field riveting, except when the use of hand tools is permitted by the Engineer. Rivets larger than $\frac{7}{8}$ inch in diameter shall not be driven by hand. Cup-faced dollies, fitting the head closely to insure good bearing, shall be used. Connections shall be accurately and securely fitted up before the rivets are driven. Drifting shall be only such as to draw the parts into position and not sufficient to

enlarge the holes or distort the metal. Unfair holes shall be reamed or drilled. Rivets shall be heated uniformly to a light cherry-red color and shall be driven while hot. They shall not be overheated or burned. Rivet heads shall be full and symmetrical, concentric with the shank, and shall have full bearing all around. They shall not be smaller than the heads of the shop rivets. Rivets shall be tight and shall grip the connected parts securely together. Caulking or recupping will not be permitted. In removing rivets, the surrounding metal shall not be injured; if necessary, they shall be drilled out.

Bolted Connections

813. In bolted connections, the bolts shall be drawn up tight and the threads burred at the face of the nut with a pointed tool.

Pin Connections

814. Pilot and driving nuts shall be used in driving pins. They will be furnished with the steel work and shall be returned to the Purchaser on completion of the work. Pins shall be so driven that the members will take full bearing on them. Pin nuts shall be screwed up tight and the threads burred at the face of the nut with a pointed tool.

Misfits

815. Corrections of minor misfits and a reasonable amount of reaming and cutting of excess stock from rivets will be considered a legitimate part of the erection. Any error in shop work which prevents the proper assembling and fitting up of parts by the moderate use of drift pins or a moderate amount of reaming and slight chipping or cutting, shall be reported immediately to the Inspector, and his approval of the method of correction obtained. The correction shall be made in the presence of the Inspector, who will check the time and material. The Contractor shall render within thirty days an itemized bill for such work of correction for the approval of the Engineer.

Removal of Old Structure and Falsework

816. If stipulated in the agreement, the Contractor shall dismantle the old structure which, unless otherwise provided, shall be the property of the Purchaser, and shall dispose of it in the immediate vicinity of the bridge site as the Engineer may direct. If the old structure is to be re-erected, it shall be dismantled without unnecessary damage and the parts match-marked and carefully piled.

Upon completion and before final acceptance, the Contractor shall remove all falsework, excavated or useless materials, rubbish and temporary buildings, replace or renew any fences damaged and restore in an acceptable manner all property, both public and private, which may have been damaged during the prosecution of his work, and shall leave the bridge site and adjacent highways in a neat and presentable condition satisfactory to the Engineer. All excavated material or falsework placed in the stream channel during construction shall be removed by the Contractor before final acceptance.

Superintendence and Workmen

817. During the progress of the work the Contractor shall have a competent foreman or superintendent in personal charge of the work. Instructions given to the foreman or superintendent shall be considered as given to the Contractor. All work shall be done by skilled, competent workmen.

Responsibility

818. The Contractor shall be responsible for loss of, or damage to, materials; for all damage to persons or property; and for casualties of every description caused by his operations during the progress of the work.

Inspection

819. The work shall be subject at all times to inspection by the Engineer.

Laws and Permits

820. The Contractor shall comply with Federal, State and local laws, regulations, and ordinances, and shall obtain at his own expense the necessary permits for his operations.

(IX) FIELD PAINTING

General Conditions

901. The requirements of Articles 601 to 608, inclusive, shall apply to field painting.

902. The Contractor shall protect pedestrian, vehicular and other traffic upon or underneath the bridge and also all portions of the bridge superstructure and substructure against damage or disfigurement by spatters, splashes and smirches of paint or paint materials.

Number of Coats and Color

903. Unless otherwise specified, field painting shall consist of two coats applied after erection.

The color of the paint shall be determined by the Engineer and the coats shall be sufficiently different in color to permit detection of incomplete application.

Field Painting

904. As soon as the field cleaning has been done to the satisfaction of the Inspector, the heads of field rivets and bolts, and any surfaces from which the shop coat of paint has been worn off or has become otherwise defective, shall be covered with one coat of the same paint as was used in the shop.

When the paint applied for touching up rivet heads and abraded surfaces has become dry, the first field coat may be applied. In no case shall a coat be applied until the previous coat has dried throughout the full thickness of the paint film.

To secure a maximum thickness of paint film on rivet heads and edges of plates, angles, and other rolled shapes, these parts shall be painted an extra coat in advance of the general application of each field coat.

Small cracks and cavities which have not been sealed in a watertight manner by the first field coat shall be filled with red lead paste before the second field coat is applied.

(X) GENERAL FEATURES OF DESIGN

Materials

1001. Materials shall conform to the requirements specified in Section II. Except where otherwise provided, all members shall be of structural steel and rivets shall be of rivet steel.

Castings shall be steel or malleable castings, or cast iron. Cast iron shall be used only where specifically authorized by the Engineer.

Phosphor-bronze may be used in expansion bearings.

Width of Roadway and Sidewalk

1002. The width of roadway shall be the clear width measured at right angles to the longitudinal center line of the bridge between the tops of curbs or guard timbers. If there are no curbs or guard timbers, it shall be the clear width inside to inside of the handrails or other guards along the sides of the structure.

The width of the sidewalk shall be the clear width, measured at right angles to the longitudinal center line of the bridge, from the extreme inside

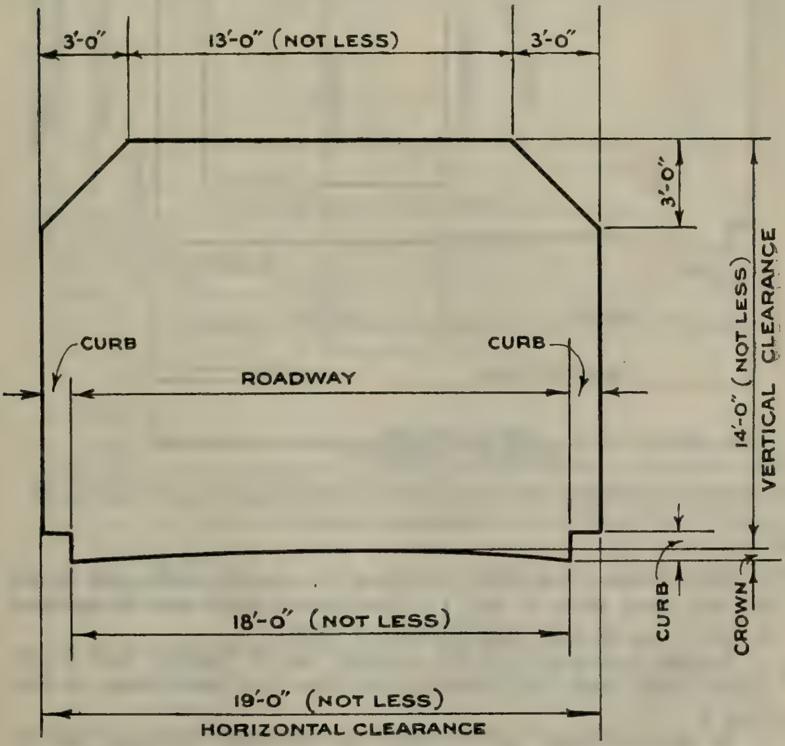


Fig. 1—Clearance Diagram Two-Lane Highway Traffic

portion of the handrail to the face of the curb or guard timber, except that if there is a truss, girder, or parapet wall adjacent to the roadway curb, the width shall be measured to its extreme outside portion.

Clearances

1003. The horizontal clearance shall be the clear width, and the vertical clearance the clear height, available for the passage of vehicular traffic, as shown on the clearance diagrams.

Unless otherwise provided the several parts of the structure shall be constructed to secure the following limiting dimensions or clearances for traffic.

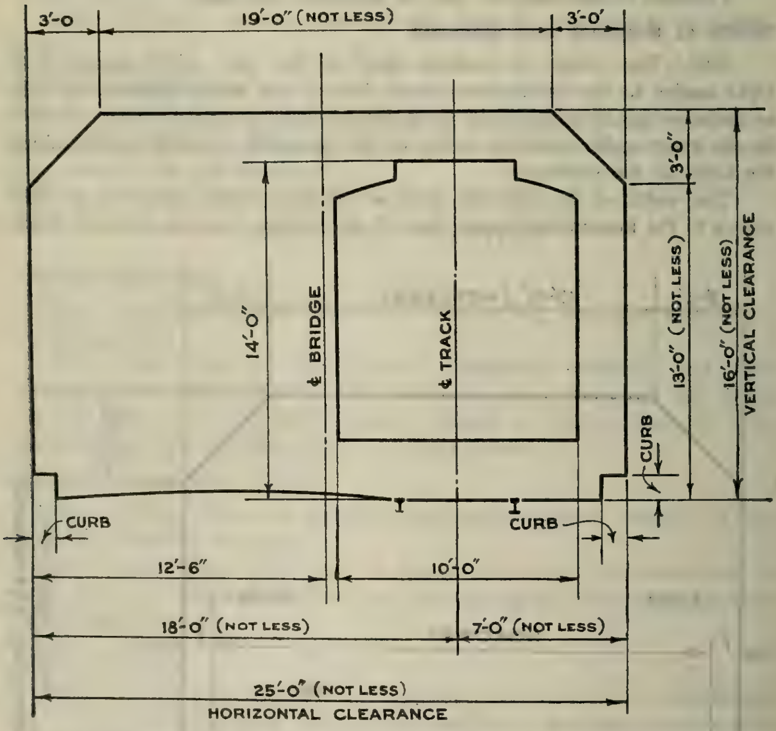


Fig. 2—Clearance Diagram Single Track Railway and One-Lane Highway Traffic

The clearances and width of railway for two-lane traffic shall be not less than those shown in Fig. 1. The roadway width shall be increased at least 9 feet for each additional lane of traffic.

Bridges constructed for the combined use of highway and electric railway traffic shall have clearances not less than those shown in Fig. 2 and 3.

In cases involving curved tracks, the horizontal clearances shall be increased an amount corresponding to that required to maintain the specified clearances. If the outer rail is superelevated, the clearances shall be correspondingly increased.

Curbs

1004. The face of the curb shall be not less than 6 inches and preferably not less than 9 inches from that portion of the railing, truss, or girder nearest the roadway. The curb height shall be not less than 9 inches above the adjacent finished roadway surface, when not otherwise determined, or provided by law.

Concrete curbs shall be designed to resist a lateral force of not less than 500 lb. per linear foot of curb, applied at the top of the curb.

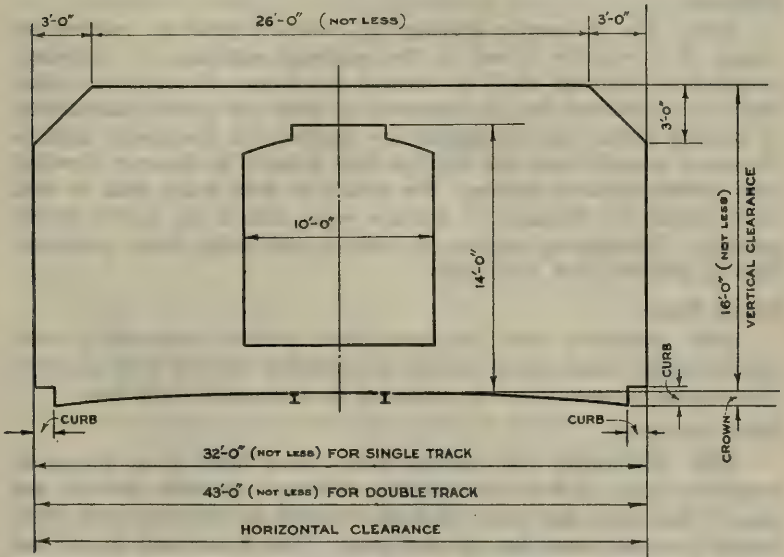


Fig. 3—Clearance Diagram Electric Railway and Two-Lane Highway Traffic

Railings

1005. Substantial railings along each side of the bridge shall be provided for the protection of traffic. The top of the railing shall be not less than 3 feet above the finished surface of the roadway adjacent to the curb, or if on a sidewalk, not less than 3 feet above the sidewalk floor.

Railings shall be designed to resist a horizontal force of not less than 150 lb. per linear foot, applied at the top of the railing, and a vertical force of not less than 100 lb. per linear foot.

In general, railings shall be of two classes, as follows:

(1) Railings for the protection of pedestrians on bridges in cities and villages.

(2) Railings for use on country bridges not subject to general pedestrian traffic.

Metal railings of the first class shall consist of an upper and a lower horizontal rail connected by a suitable web. The clear distance between the top of the curb or the sidewalk and the lower rail shall not exceed 6 inches. Metal railings of the second class may consist of not less than two lines of horizontal rails of approved section. In each connection of the railing to the posts, truss members, etc., there shall be not less than two rivets or bolts. Provision shall be made for movement due to temperature.

Openings in concrete railings of the first class shall be proportioned with due regard to the safety of persons using the structure. Provision shall be made for the expansion and contraction of concrete railings at intervals consistent with the design.

Drainage

1006. The transverse drainage of roadways shall be secured by means of a suitable crown in the roadway surface. If necessary, longitudinal drainage shall be secured by means of scuppers, which shall be of sufficient size and number to drain the gutters adequately. If drainage gutters and downspouts are required, the downspouts shall be of cast or wrought iron pipe not less than 4 inches in diameter, provided with suitable clean-out fixtures. The details of floor drains shall be such as to prevent the discharge of drainage water against any portion of the structure. Overhanging portions of concrete and timber floors preferably shall be provided with drip beads.

Paved Floors

1007. Pavements other than wood block shall be supported by reinforced concrete slabs carried on steel or reinforced concrete floor members. Wood block pavements may be supported by a creosoted plank base.

Blast Protection

1008. On bridges over railroad tracks, metal likely to be injured by locomotive gases shall be protected by concrete. Concrete surfaces less than 20 feet above the tracks, shall be protected by cast iron blast plates located over the center line of each track. The plates shall be not less than 3 feet wide and not less than ¾ inch thick and so supported that they may be replaced readily. Pockets which will hold locomotive gases shall be avoided if practicable.

Utilities

1009. Where required, provisions shall be made for trolley wire supports and poles for lights, and suitable spaces shall be made available for electric conduits, water pipes and gas pipes.

Types of Bridges

1010. The different types of bridges may be used within the following limits, due consideration being given to transportation and erection conditions in selecting the type to be used.

Rolled beams for spans up to	60 feet
Plate girders for spans	30 to 125 feet
Riveted half-through trusses for spans	45 to 100 feet
Riveted trusses for spans above	90 feet
Pin-connected trusses for spans above	150 feet

Classification of Bridges

1011. The classification of bridges with reference to traffic shall be as follows:

Class AA. Bridges for specially heavy traffic units in locations where the passage of such loads is frequent.

Class A. Bridges for normally heavy traffic units and the occasional passage of specially heavy loads.

Class B. Bridges for light traffic units and the occasional passage of normally heavy loads. Class B bridges shall be considered as temporary or semi-temporary structures.

Class C. Bridges for electric railway traffic in addition to highway traffic. The latter may correspond to any one of the classes described above.

(XI) LOADS

Loads

1101. Structures shall be proportioned for the following loads and forces:

(a) Dead Load.
(b) Live Load.
(c) Impact or dynamic effect of the live load.
(d) Lateral forces.
(e) Other forces, when they exist, as follows:
Longitudinal force; centrifugal force; and thermal forces.

Members shall be proportioned for the combination of loads and forces producing the maximum total stress, except as otherwise provided herein.

Upon the stress sheets a diagram of the assumed live loads shall be shown and the stresses due to the various loads shall be shown separately.

Dead Load

1102. The dead load shall consist of the weight of the structure complete, including the roadway, sidewalks, and car tracks, pipes, conduits, cables and other public utility services.

The snow and ice load is considered to be offset by an accompanying decrease in live load and impact and shall not be included except under special conditions.

In the case of structures having concrete slab floors, an adequate allowance shall be made in the design dead load to provide for the weight of a wearing surface. This allowance will depend upon the type of wearing surface contemplated; it shall be in addition to the weight of any monolithically placed concrete wearing surface; and shall be not less than 15 lb per square foot of roadway.

The following weights are to be used in computing the dead load:

	Weight per cubic foot, Pounds
Steel	490
Cast iron	450
Timber (treated or untreated)	60
Concrete, plain or reinforced	150
Loose sand and earth	100
Rammed sand or gravel, and ballast	120
Macadam or gravel, rolled	140
Cinder filling	60
Pavement, other than wood block	150
Railway rails and fastenings	150 lb. per linear foot of track

Live Load

1103. The live load shall consist of the weight of the applied moving load of vehicles, cars and pedestrians.

Highway Live Loads

1104. The highway live load on the roadway portion of the bridge shall consist of trains of motor trucks, or equivalent loads, as hereinafter specified. Each loading is designated by the letter H, followed by a numeral indicating the gross weight in tons of the heaviest loaded truck in the train.

Traffic Lanes

1105. The truck trains or equivalent loads shall be assumed to occupy traffic lanes, each having a width of 9 feet corresponding to the standard truck clearance width. Within the curb to curb width of the roadway, the traffic lanes shall be assumed to occupy any position which will produce the maximum stress, but which will not involve overlapping of adjacent lanes, nor place the center of the lane nearer than 4 feet 6 inches to the roadway face of the curb.

Trucks

1106. The wheel spacing, weight distribution, and clearance of the trucks used for design purposes shall be as shown in Fig. 4.

Highway Loading

1107. The highway loading shall be of three classes: namely, H20, H15, and H10, and may be either truck train loadings or equivalent loadings. Loadings H15 and H10 are 75 per cent and 50 per cent, respectively, of Loading H20.

(a) Truck Train Loadings. The truck train loading shall be as shown in Fig. 5 and shall be used for loaded lengths of less than 60 feet. It shall consist of one truck of the gross weight indicated by the loading class followed by, or preceded by, or both followed and preceded by, a line of trucks of indefinite length, each of the following or preceding trucks having a gross weight of three-fourths of the gross weight indicated by the loading class.

Trucks in adjacent lanes shall be considered as headed in the same direction.

(b) Equivalent Loading. The equivalent loading shall be as shown in Fig. 6, and shall be used only for loaded lengths of 60 feet or greater.

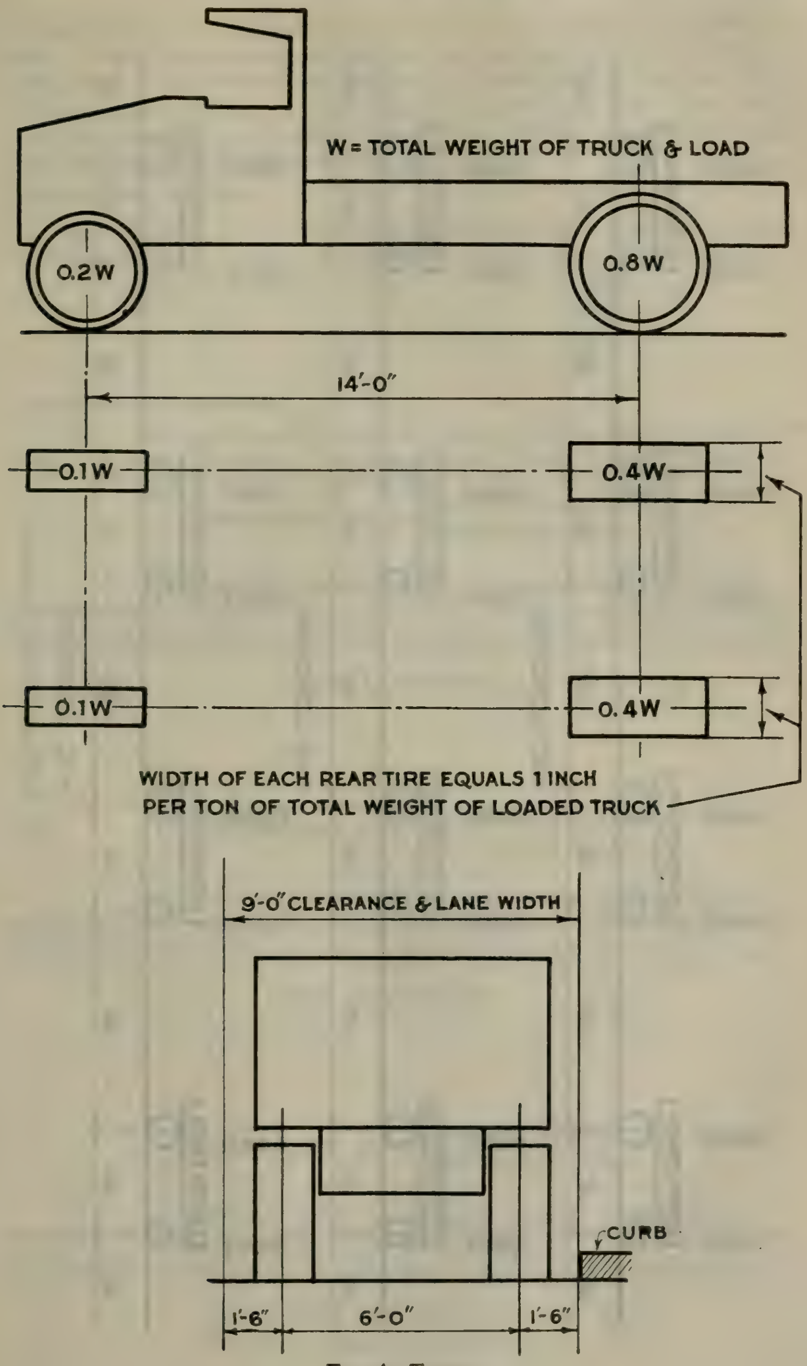

W = TOTAL WEIGHT OF TRUCK & LOAD
0.2W
0.8W
14'-0"
0.1W
0.4W
0.1W
0.4W
WIDTH OF EACH REAR TIRE EQUALS 1 INCH PER TON OF TOTAL WEIGHT OF LOADED TRUCK
9'-0" CLEARANCE & LANE WIDTH
CURB
1'-6"
6'-0"
1'-6"

Fig. 4—Truck

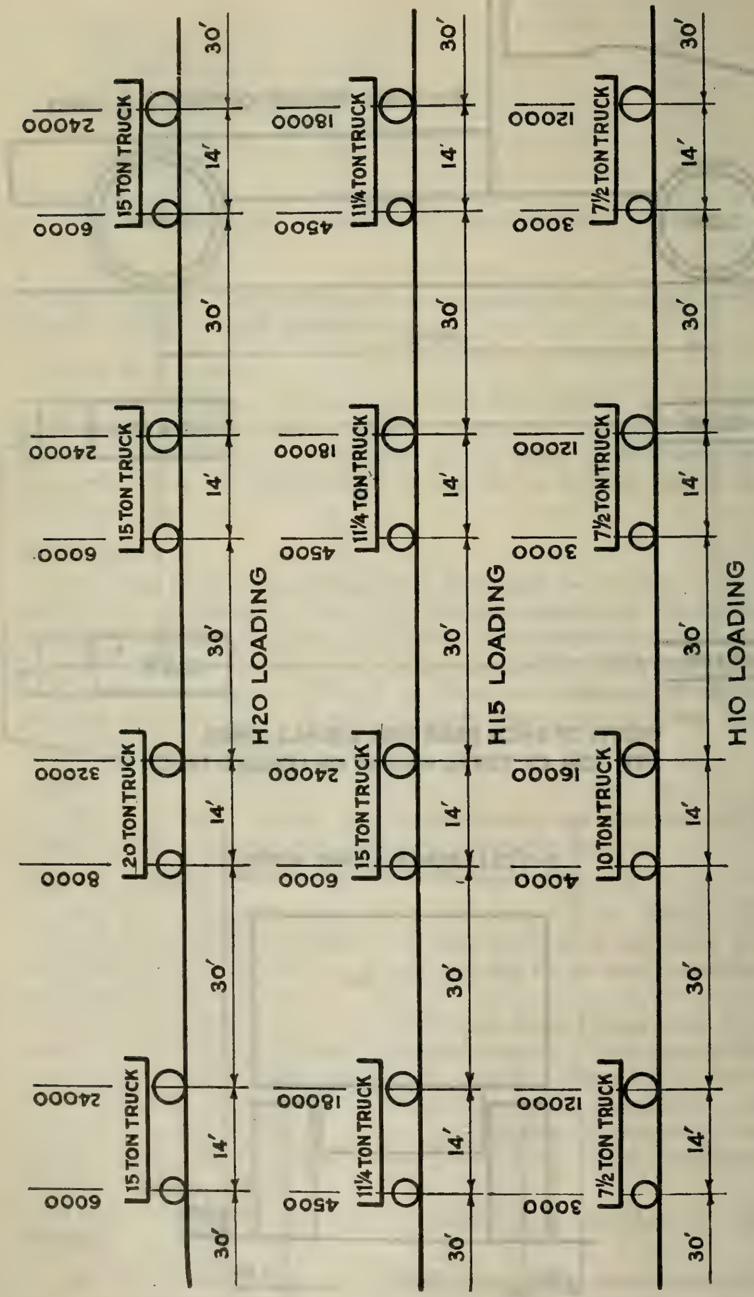


Fig. 5—Truck Train Loading

It shall consist of a uniform load per linear foot of traffic lane combined with a single concentrated load so placed on the span as to produce maximum stress. The concentrated load shall be considered as uniformly distributed across the lane on a line normal to the center line of the lane. For the computation of moments and shears, different concentrated loads shall be used as indicated in Fig. 6.

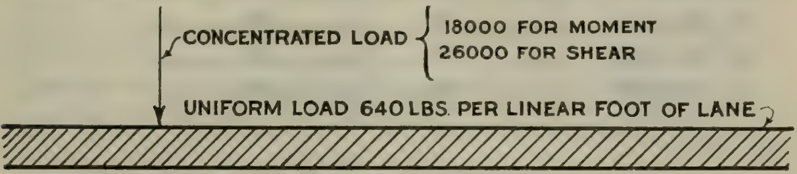
Selection of Loadings

1108. Bridges of the different classes shall be designed for the loadings as follows:

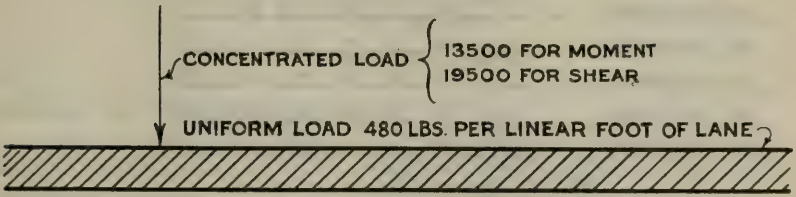
Class of Bridge	*Loading*
AA	H20
A	H15
B	H10

Application of Loadings

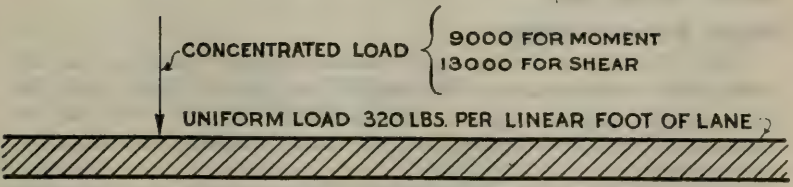
1109. The loadings shall be applied by that one of the following methods which produces the greater maximum stress in the member considered,



H 20 LOADING



H 15 LOADING



H 10 LOADING

Fig. 6—Equivalent Loading

allowance being made for the reduced load intensities hereinafter specified for roadways having loaded widths in excess of 18 ft.

(1) Each traffic lane loading shall be considered as a unit, and the number and position of the loaded lanes shall be such as will produce maximum stress.

(2) The roadway shall be considered as loaded over its entire width with a load per foot of width equal to one-ninth of the load of one traffic lane.

Reduction in Load Intensity

1110. If the loaded width of the roadway exceeds 18 feet, the specified loads shall be reduced one per cent for each foot of loaded roadway width in excess of 18 feet with a maximum reduction of twenty-five per cent, corresponding to a loaded roadway width of 43 feet. If the loads are lane loads, the loaded width of the roadway shall be the aggregate width of the lanes considered; if the loads are distributed over the entire width of the roadway, the loaded width of the roadway shall be the full width of roadway between curbs.

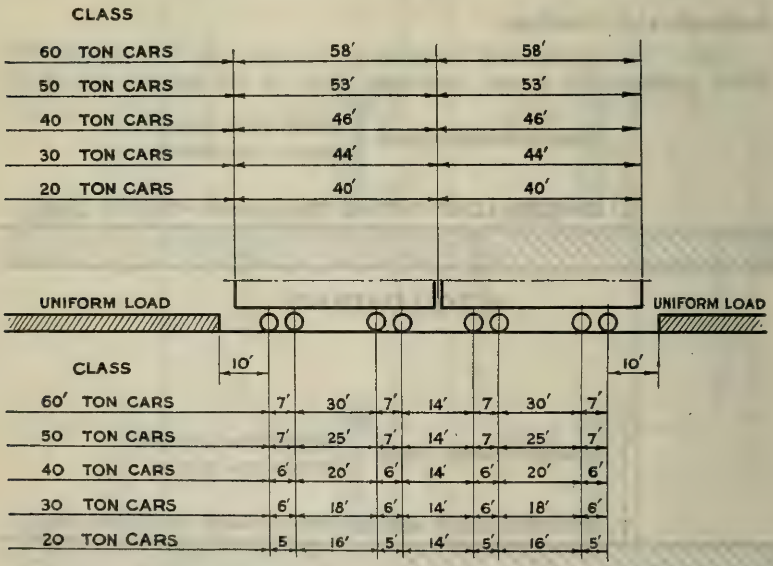

CLASS
60 TON CARS 58′ 58′
50 TON CARS 53′ 53′
40 TON CARS 46′ 46′
30 TON CARS 44′ 44′
20 TON CARS 40′ 40′
UNIFORM LOAD
UNIFORM LOAD
10′
10′
CLASS
60′ TON CARS 7′ 30′ 7′ 14′ 7 30′ 7′
50 TON CARS 7′ 25′ 7′ 14′ 7 25′ 7′
40 TON CARS 6′ 20′ 6′ 14′ 6′ 20′ 6′
30 TON CARS 6′ 18′ 6′ 14′ 6′ 18′ 6′
20 TON CARS 5 16′ 5′ 14′ 5′ 16′ 5′

Fig. 7—Electric Railway Loading

Electric Railway Loading

1111. If highway bridges carry electric railway traffic, the railway loading shall be determined on the basis of the class of traffic which the bridge may be expected to carry. The possibility that the bridge may be required to carry the freight cars of steam railroads shall be given consideration.

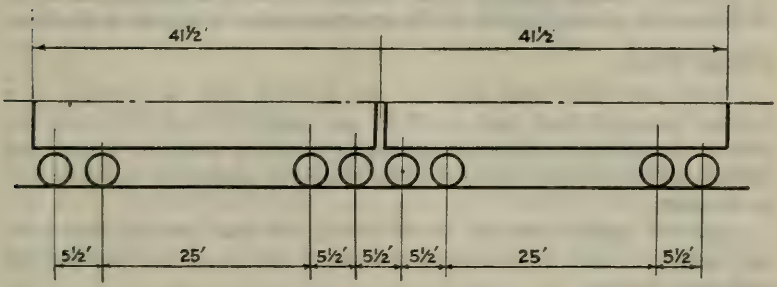
When not otherwise specified, the electric railway loading on each track shall be a train of two electric cars followed by, or preceded by, or both followed and preceded by, a uniform load. The cars shall be of one of the classes shown in Fig. 7. The class is designated by a numeral indicating the total loaded weight of each car. The uniform load per foot of track following or preceding electric cars shall be the uniform load corresponding to the class of highway loading specified (640 lb. per linear foot for H20 loading). The electric railway loading shall be assumed to occupy 10 feet of the roadway width.

For freight car loading, one of the classes of cars shown in Fig. 8 may be assumed in the absence of more exact data.

The railway loading used shall be shown on the stress sheets.

1112. Highway bridges carrying electric railway traffic shall be designed for the following loading conditions:

(1) The highway loading on any portion of the roadway area including that portion occupied by the railway.
(2) The electric railway loading on the car tracks and the highway loading on the remaining traffic lanes.



TOTAL LOADED WEIGHT PER CAR
INCLUDING 10 PERCENT OVERLOAD
40 TON CAPACITY-132000 LBS.
70 TON CAPACITY-212000 LBS.

Fig. 8—Freight Car Loading

Sidewalk and Foot Bridge Loading

1113. Sidewalk floors, stringers, and their immediate supports shall be designed for a live load of not less than 100 lb. per square foot of sidewalk area.

Girders or trusses of bridges with sidewalks shall be designed for a sidewalk live load determined by the following formula:

$$P=\left(40+\frac{3000}{L}\right)\left(\frac{55-W}{50}\right), \text{ in which:}$$

P = live load in lb. per square foot of sidewalk area, but not to exceed 100 lb. per square foot.
L = loaded length of sidewalk in feet.
W = width of sidewalk in feet.

In calculating stresses in structures which support cantilevered sidewalks, the sidewalk shall be considered as fully loaded on only one side of the structure if this condition produces maximum stress.

All parts of foot bridges shall be designed for a live load of not less than 100 pounds per square foot.

Impact

1114. Live load stresses, except those due to sidewalk loads and centrifugal, tractive, and wind forces, shall be increased by an allowance for dynamic, vibratory, and impact effects.

The amount of this allowance or increment is expressed as a fraction of the live load stress, and for both electric railway and highway loadings shall be determined by the formula:

$$I = \frac{50}{L + 125}, \text{ in which:}$$

I = impact fraction.
L = the length in feet of the portion of the span which is loaded to produce the maximum stress in the member considered.

Longitudinal Force

1115. Provision shall be made for the effect of a longitudinal force of 10 per cent of the live load on the structure, acting 4 feet above the floor.

Lateral Forces

1116. (a) The wind force on the structure shall be assumed as a moving horizontal load equal to 30 lb. per square foot on 1½ times the area of the structure as seen in elevation including the floor system and railings and on one-half the area of all trusses or girders in excess of two in the span.

(b) The lateral force due to the moving live load and the wind pressure against it, shall be considered as acting 6 feet above the roadway and shall be as follows:

Highway bridges, 200 lb. per linear foot.
Highway bridges carrying electric railway traffic, 300 lb. per linear foot.

(c) The total assumed wind force shall be not less than 300 lb. per linear foot in the plane of the loaded chord and 150 lb. per linear foot in the plane of the unloaded chord on truss spans, and not less than 300 lb. per linear foot on girder spans.

(d) In calculating the uplift, due to the foregoing lateral forces, in the posts and anchorages of viaduct towers, highway viaducts shall be considered as loaded on the leeward traffic lane with a uniform load of 400 lb. per linear foot of lane, and viaducts carrying electric railway traffic in addition to highway traffic shall be considered as loaded on the leeward track with a uniform load of 800 lb. per linear foot of track.

(e) A wind pressure of 50 lb. per square foot on the unloaded structure, applied as specified above in paragraph (a), shall be used if it produces greater stresses than the combined wind and lateral forces of paragraphs (a) and (b).

Centrifugal Force

1117. If the electric railway track is curved, the structure shall be designed to resist a lateral force equal to 10 per cent of the moving railway loading. This lateral force shall be considered as acting 4 feet above the top of rail.

Thermal Forces

1118. In fixed arched spans, provision shall be made for the stresses resulting from the following variations in temperature:

Moderate climate, from 0 degrees to 120 degrees Fahr.
Cold climate, from —30 degrees to 120 degrees Fahr.

The rise and fall in temperature shall be figured from an assumed temperature at the time of erection.

(XII) DISTRIBUTION OF LOADS

Distribution of Wheel Loads to Stringers and Floorbeams

1201. Shear.—In calculating end shears and end reactions in transverse floorbeams and longitudinal beams and stringers, no lateral or longitudinal distribution of the wheel load shall be assumed.

Bending Moment in Stringers.—In calculating bending moments in longitudinal beams or stringers, no longitudinal distribution of the wheel loads shall be assumed. The lateral distribution shall be determined as follows:

(a) Interior Stringers.

Interior stringers shall be proportioned for loads determined in accordance with the following table, except that when the limiting stringer spacings are exceeded, the stringer loads shall be determined by the reactions of the truck wheels, assuming the flooring between stringers to act as a simple beam.

KIND OF FLOOR	Floor designed for one traffic lane		Floor designed for two or more traffic lanes	
	Fraction of a wheel load to each stringer	Limiting stringer spacing in feet	Fraction of a wheel load to each stringer	Limiting stringer spacing in feet
Plank	$\frac{S}{4.0}$	4.0	$\frac{S}{3.5}$	5.0
Strip 4 in. in thickness or wood block on 4 in. plank sub-floor	$\frac{S}{4.5}$	4.5	$\frac{S}{3.75}$	5.5
Strip 6 in. or more in thickness	$\frac{S}{5.0}$	5.0	$\frac{S}{4.0}$	6.0
Concrete	$\frac{S}{6.0}$	6.0	$\frac{S}{4.5}$	10.0

S=spacing of stringers in feet.

(b) Outside Stringers.

The live load supported by outside stringers shall be the reaction of the truck wheels, assuming the flooring to act as a simple beam between stringers.

(c) Total Capacity of Stringers.

The combined load capacity of the beams in a panel shall not be less than the total live and dead load in the panel.

Bending Moment in Floorbeams.—In calculating bending moments in floorbeams, no transverse distribution of the wheel loads shall be assumed.

If longitudinal stringers are omitted and the floor is supported directly on the floorbeams, the latter shall be proportioned for a fraction of the wheel loads as indicated in the following table, except that when the limiting floorbeam spacing is exceeded the floorbeam loads shall be determined by the reactions of the truck wheels, assuming the flooring between floorbeams to act as a simple beam.

KIND OF FLOOR	Fraction of wheel loads to each floorbeam	Limiting floorbeam spacing in feet
Plank	$\frac{S}{4.0}$	4.0
Strip 4 in. in thickness or wood block on 4 in. plank sub-floor	$\frac{S}{4.5}$	4.5
Strip 6 in. or more in thickness	$\frac{S}{5.0}$	5.0
Concrete	$\frac{S}{6.0}$	6.0

S=spacing of floorbeams in feet.

Distribution of Wheel Loads on Concrete Slabs

1202. Bending Moment.—In calculating bending stresses due to wheel loads on concrete slabs, no distribution in the direction of the span of the slab shall be assumed. In the direction perpendicular to the span of the slab, the wheel load shall be considered as distributed uniformly over a width of slab which is termed the "effective width" and is obtained from the following formulas in which:

S = span of slab in feet.
W = width of wheel or tire in feet.
D = distance in feet from the center of the near support to the center of wheel.
E = effective width in feet for one wheel.

Case I. Main Reinforcement Parallel to Direction of Traffic.

$E = 0.7\,S + W$, in which E shall have a maximum value of 7.0 feet.

When two wheels are so located on a transverse element of the slab that their effective widths overlap, the effective width for each wheel shall be $\frac{1}{2}(E + C)$, in which E is the value determined by the formula above and C is the distance between centers of wheels.

Case II. Main Reinforcement Perpendicular to Direction of Traffic.

$E = 0.7\ (2D + W)$.

For this case the bending moment on a strip of slab one foot in width shall be determined by placing the wheel loads in the position to produce the maximum bending, assuming no distribution; determining the effective width for each wheel; and assuming the load of each wheel on the one-foot strip to be the wheel load divided by its respective effective width.

The design assumption of Case II does not provide for the effect of loads near unsupported edges. Therefore, at the ends of the bridge and at intermediate points where the continuity of the slab is broken, the edges of the slab shall be supported by diaphragms or other suitable means.

SHEAR.—Slabs designed for bending moment in accordance with the foregoing rules and for the wheel loads contemplated by these specifications may be considered adequate for shear without special reinforcement.

Distribution of Electric Railway Wheel Loads

1203. Electric railway wheel loads shall be assumed to be uniformly distributed longitudinally over a length of 3 feet. In the case of ballasted floors, a lateral distribution of 10 feet for an axle load shall be assumed.

(XIII) UNIT STRESSES

General

1301. Except as modified elsewhere in these specifications the several parts of a structure shall be so proportioned that the unit stresses will not exceed those specified below.

Members of structural steel shall be so proportioned that an increase of the highway live load by 100 per cent or the electric railway live load by 50 per cent will not produce combined unit stresses in the members more than those specified for dead load.

Unless otherwise noted, unit stresses are given in pounds per square inch.

Structural Grade and Rivet Steel

1302. For structural grade and rivet steel:

TENSION

	For Live Load and Lateral Forces	*For Dead Load*
Axial tension, structural members, net section	16,000	24,000
Bolts, area at root of thread.....	10,000	15,000
AXIAL COMPRESSION		
Axial compression, gross section..	$\dfrac{16,000}{1+\dfrac{1}{13,500}(l/r)^2}$	$\dfrac{24,000}{1+\dfrac{1}{13,500}(l/r)^2}$
but not to exceed the value for $l/r=40$ $l=$ length of the member, in inches. $r=$ least radius of gyration of the member, in inches.		
Compression splice material, gross section	16,000	24,000

BENDING ON EXTREME FIBER		
Compression in flanges of beams and plate girders	$\dfrac{16,000}{1+\dfrac{1}{2,000}(l/b)^2}$	$\dfrac{24,000}{1+\dfrac{1}{2,000}(l/b)^2}$
l = length in inches of the unsupported flange between lateral connections or knee braces.		
b = flange width, in inches.		
Tension in rolled shapes, built sections and girders net section	16,000	24,000
Pins	24,000	36,000
DIAGONAL TENSION		
In webs of girders and rolled beams, at sections where maximum shear and bending occur simultaneously	16,000	24,000
SHEAR		
Girder webs, gross section	10,000	15,000
Pins and shop driven rivets	12,000	18,000
Power driven field rivets and turned bolts	10,000	15,000
Hand driven rivets and unfinished bolts	8,000	12,000
BEARING		
Pins, steel parts in contact and shop driven rivets	24,000	36,000
Power driven field rivets and turned bolts	20,000	30,000
Hand driven rivets and unfinished bolts	16,000	24,000
Expansion rollers, pounds per linear inch	$600\,d$	$900\,d$
d = diameter of roller in inches.		

In proportioning rivets, the nominal diameter shall be used.

The effective bearing area of a pin, a bolt, or a rivet shall be its diameter multiplied by the thickness of the metal on which it bears.

In metal ⅜ inch thick and over, half the depth of countersink shall be omitted in calculating bearing area. In metal less than ⅜ inch thick, countersunk rivets shall not be assumed to carry stress.

Steel Castings

1303. For steel castings, three-fourths of the unit stresses specified above for structural grade steel shall apply.

Cast Iron

1304. For cast iron:

Bending on extreme fiber	3,000
Shear	3,000
Direct compression (short columns)	12,000

Bronze

1305.	Bearing on bronze expansion bearings	2,000

Bearing on Masonry

1306.	Bearing on granite masonry	800
	Bearing on sandstone and limestone masonry	400
	Bearing on concrete masonry	600

(XIV) PROPORTIONING OF PARTS

Ambiguity of Stress

1401. Structures shall be so designed as to avoid, as far as practicable, ambiguity in the determination of the stresses.

Number of Trusses or Girders

1402. Preferably through spans shall have only two trusses or girders.

Spacing of Trusses and Girders

1403. Main trusses and girders shall be spaced a sufficient distance apart center to center, to be secure against overturning by the assumed lateral forces.

Effective Span

1404. For the calculation of stresses, span lengths shall be assumed as follows:

Beams and girders, distance between centers of bearings.
Trusses, distance between centers of end pins or of bearings.
Floor beams, distance between centers of trusses or girders.
Stringers, distance between centers of floor beams.

Effective Depth

1405. For the calculation of stresses, effective depths shall be assumed as follows:

Riveted trusses, distance between centers of gravity of the chords.
Pin-connected trusses, distance between centers of chord pins.
Plate girders, distance between centers of gravity of the flanges, but not to exceed the distance back to back of flange angles.

Alternate Stresses

1406. Members subject to alternate stresses of tension and compression, due to the combination of dead, live, impact and centrifugal stresses, shall be proportioned for the kind of stress requiring the larger section.

If the alternate stresses occur in succession during one passage of the live load, each shall be increased by 50 per cent of the smaller. The connections of such members shall be proportioned for the sum of the net alternate stresses not so increased.

If the live load and dead load stresses are of opposite sign, only 70 per cent of the dead load stress shall be considered as effective in counteracting the live load stress.

Combined Stresses

1407. Members subject to both axial and bending stresses shall be proportioned so that the combined fiber stresses will not exceed the specified axial unit stress. If members are continuous over panel points, three-fourths of the bending stress, computed as for a simple beam, shall be added to the axial stress.

Secondary Stresses

1408. Designing and detailing shall be done so as to avoid secondary stresses as far as practicable. In ordinary trusses without sub-paneling, no account usually need be taken of the secondary stresses in any member whose width measured in the plane of the truss is less than one-tenth of the length of the member. If the width is greater than one-tenth of the length, or if sub-paneling is used, secondary stresses due to deflection of the truss shall be considered.

Rolled Beams

1409. Rolled beams shall be proportioned by the moments of inertia of their net sections.

Limiting Lengths of Members

1410. For compression members, the ratio of unsupported length to the least radius of gyration shall not exceed 120 for main and stiffening members nor 140 for laterals and sway bracing. In proportioning the top chords of half-through trusses, the unsupported length shall be assumed as the length between laterally supported panel points.

For main riveted tension members, the ratio of length to least radius of gyration shall not exceed 200.

Depth Ratios

1411. The ratio of the depth to the length of spans preferably shall be not less than the following:

For trusses	one-tenth
For plate girders	one-fifteenth
For rolled beams used as girders	one-twentieth

If depths less than these are used, the sections shall be so increased that the maximum deflection will not be greater than if these ratios had not been exceeded.

Symmetrical Sections

1412. Main members shall be proportioned so that their gravity axes will be as nearly as practicable in the center of the section.

Effective Area of Angles in Tension

1413. The effective area of a single angle tension member, or of each angle of a double angle tension member in which the angles are connected back to back on the same side of a gusset plate, shall be assumed as the net area of the connected leg plus half of the area of the unconnected leg.

If a double angle tension member is connected with the angles back to back on opposite sides of a gusset plate, the full net area of the angles shall be considered as effective. If the angles connect to separate gusset plates, as in the case of a double-webbed truss, and the angles are connected by stay plates located as near the gussets as practicable, or by other effective means, the full net area of the angles shall be considered as effective. If the angles are not so connected, only 80 per cent of the net area shall be considered as effective.

Lug angles shall not be considered as effective in transmitting stress.

Minimum Thickness of Metal

1414. Gusset plates shall be not less than ⅜ inch in thickness. Other structural steel, except for fillers and in railings, shall be not less than 5/16 inch in thickness.

Metal subjected to marked corrosive influence shall be increased in thickness or specially protected against corrosion.

Plates in Compression

1415. The thickness of web plates of compression members shall be not less than one-thirtieth of the transverse distance between the lines of rivets connecting them to the flanges. The thickness of cover plates of compression members and cover plates on the compression flanges of plate girders preferably shall be not less than one-fortieth of the transverse distance between the lines of rivets connecting them to the flanges, but the minimum may be one-fiftieth of this distance, provided that the width of the plate between the connecting lines of rivets in excess of 40 times the thickness shall not be considered as effective in resisting stress.

Outstanding Legs of Angles

1416. The widths of the outstanding legs of angles in compression (except where reinforced by plates) shall not exceed the following:

In girder flanges, twelve times the thickness.
In main members carrying axial stress, twelve times the thickness.
In bracing and other secondary members, sixteen times the thickness.

Size of Pins

1417. Pins shall be proportioned for the maximum shears and bending moments produced by the stresses in the members connected. If there are eye-bars among the parts connected, the diameter of the pin shall be not less than three-fourths of the width of the widest bar.

(XV) GENERAL DETAILS OF DESIGN

Size of Rivets

1501. Rivets shall be of the size shown on the drawings but generally shall be ¾ inch or ⅞ inch in diameter. Rivets ⅝ inch in diameter shall not be used in members carrying calculated stress except in 2½ inch legs of angles and in flanges of 6-inch and 7-inch beams and channels.

The diameter of rivets in angles carrying calculated stress shall not exceed one-fourth of the width of the leg in which they are driven. In angles whose size is not determined by calculated stress, ⅝-inch rivets may be used in 2-inch legs, ¾-inch rivets in 2½-inch legs, ⅞-inch rivets in 3-inch legs, and 1-inch rivets in 3½-inch legs.

Structural shapes which do not admit the use of ⅝-inch diameter rivets shall not be used except in hand rails.

Pitch of Rivets

1502. The minimum distance between centers of rivets shall be three times the diameter of the rivet but preferably shall be not less than the following:

For 1-inch rivets, 3½ inches.
For ⅞-inch rivets, 3 inches.
For ¾-inch rivets, 2½ inches.
For ⅝-inch rivets, 2¼ inches.

Pitch in Ends of Compression Members

1503. In the ends of compression members the pitch of rivets connecting the component parts of the member shall not exceed four times the diameter of the rivet for a length equal to 1½ times the maximum width of the member. Beyond this point the pitch shall be increased gradually for a length equal to 1½ times the maximum width of the member until the maximum pitch is reached.

Maximum Pitch

1504. The maximum pitch in the line of stress shall not exceed 6 inches or 16 times the thickness of the thinnest outside plate or angle connected, except that in angles having two gage lines with the rivets staggered, the pitch in each line may be twice that given by these rules, with a maximum of 10 inches.

Stitch Rivets

1505. If two or more web plates are in contact, they shall be held together by stitch rivets. In compression members, the stitch rivets shall be spaced, in the direction perpendicular to the line of stress, not more than 24 times the thickness of the thinnest plate, and, in the line of stress, not more than 12 times the thickness of the thinnest plate. In tension members and girders, the stitch rivets shall be spaced, in either direction, not more than 24 times the thickness of the thinnest outer plate. In tension members composed of two angles in contact, the angles shall be held together by stitch rivets having a maximum pitch of 12 inches.

Edge Distance of Rivets

1506. The minimum distance from the center of any rivet to a sheared edge shall be:

For 1-inch rivets, 1¾ inches.
For ⅞-inch rivets, 1½ inches.
For ¾-inch rivets, 1¼ inches.
For ⅝-inch rivets, 1⅛ inches.

The minimum distance from a rolled or planed edge, except in flanges of beams and channels, shall be:

For 1-inch rivets, 1½ inches.
For ⅞-inch rivets, 1¼ inches.
For ¾-inch rivets, 1⅛ inches.
For ⅝-inch rivets, 1 inch.

The maximum distance from any edge shall be eight times the thickness of the thinnest outside plate, but shall not exceed 5 inches.

Long Rivets

1507. Rivets subjected to calculated stress and having a grip in excess of 4½ diameters shall be increased in number at least one per cent for each additional $\frac{1}{16}$ inch of grip. If the grip exceeds 6 times the diameter of the rivet, specially designed rivets shall be used.

Rivets in Tension

1508. Rivets in direct tension shall, in general, not be used, but if so used their value shall be one-half that permitted for rivets in shear. Countersunk rivets shall not be used in tension.

Parts Accessible

1509. The accessibility of all parts of a structure for inspection, cleaning, and painting shall be secured by the proper proportioning of members and the design of their details.

Closed Sections and Pockets

1510. Closed sections, and pockets or depressions which will retain water shall be avoided so far as practicable. Pockets shall be provided with effective drain holes or be filled with waterproof material.

Details shall be so arranged that the retention of dirt, leaves, and other foreign matter will be reduced to a minimum. Wherever angles are used, either singly or in pairs, preferably they shall be placed with the vertical legs extending downward.

Eccentric Connections

1511. Members, including bracing, shall be so connected that their gravity axes will intersect in a point. Eccentric connections shall be avoided if practicable, but if unavoidable the members shall be so proportioned that the combined fiber stresses will not exceed the allowed axial stress.

Strength of Connections

1512. Unless otherwise provided, connections shall be proportioned to develop the full strength of the members connected.

Connections shall be made symmetrical about the axes of the members in so far as practicable. Connections, except for lacing bars and hand rails, shall contain not less than three rivets.

Splices

1513. Continuous compression members, such as chords and trestle posts, in riveted structures shall have milled ends and full contact bearing at the splices.

Splices, whether in tension or compression, shall be proportioned to develop the full strength of the members spliced and no allowance shall be made for the bearing of milled ends of compression members.

Splices shall be located as close to panel points as possible and, usually, shall be on that side of the panel point where the smaller stress occurs.

The arrangement of the plates, angles and other splice elements shall be such as to make proper provision for the stresses, both axial and bending, in the component parts of the members spliced.

Indirect Splices

1514. If splice plates are not in direct contact with the parts which they connect, the number of rivets on each side of the joint shall be in excess of the number required for a direct-contact splice to the extent of two extra transverse lines of rivets for each intervening plate.

Fillers

1515. If rivets carrying stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by enough additional rivets to carry the stress passing through the fillers. If the filler is less than ¼ inch thick it shall not be extended beyond the splicing material.

Gusset Plates

1516. Gusset or connecting plates shall be used for connecting main members, except when they are pin-connected. The rivets connecting each member shall be symmetrical with the axis of the member, so far as practicable, and the full development of the elements of the member shall be given consideration. The gusset plates shall be of ample thickness to resist shear, direct stress, and flexure, acting on the weakest or critical section of maximum stress.

Reentrant cuts shall be avoided as far as practicable.

Stay Plates

1517. The open sides of compression members shall be provided with lacing bars and shall have stay plates as near each end as practicable. Stay plates shall be provided at intermediate points where the lacing is interrupted. In main members, the length of the end stay plates between end rivets shall be not less than 1¼ times the distance between the inner lines of rivets connecting them to the flanges; and the length of intermediate stay plates between end rivets, not less than three-fourths of that distance. In lateral struts and other secondary members, the over-all length of end and intermediate stay plates shall be not less than three-fourths of the distance between the inner lines of rivets connecting them to the flanges.

The separate segments of tension members composed of shapes may be connected by stay plates or end stay plates and lacing. End stay plates shall have the same minimum length as specified for end stay plates on main compression members and intermediate stay plates shall have a minimum length of three-fourths of that specified for intermediate stay plates on main compression members. The clear distance between stay plates on tension members shall not exceed 3 feet.

The thickness of stay plates shall be not less than one-fiftieth of the distance between the inner rivet lines connecting them to the flanges. Stay plates shall be connected by not less than three rivets on each side and in members having lacing bars, the last rivet in the stay plate preferably shall also pass through the end of the adjacent bar.

Lacing Bars

1518. The lacing of compression members shall be proportioned to resist shearing stresses normal to the member not less than those determined by the formulas:

$$(1)\quad R = \frac{4I}{CL}(24{,}000 - p)$$

$$(2)\quad R = \frac{0.4pI}{CL}$$

in which

R = normal shearing stress in pounds.
I = moment of inertia of section about an axis perpendicular to the plane of the lacing.
C = distance from neutral axis to extreme fiber, in inches.
L = length of member, in inches.
p = average compressive unit stress in the member; $= \frac{P}{A}$
P = total stress in the member including the increases in live load, specified in Article 1301.
A = gross section of the member, in square inches.

The greater of the values given by these two formulas shall be used.

If the lacing of a horizontal or inclined compression member is in a vertical plane, the shear in the lacing caused by the weight of the member shall be added to the shear calculated by the formulas above.

The shear shall be considered as divided equally among all shear resisting elements in parallel planes, whether made up of continuous plates or of lacing. The size of the bar shall be determined by the formula for axial compression in Section XIII in which L shall be taken as the distance between the connections to the main sections.

The minimum width of lacing bars shall be:

For 1-inch rivets, 2¾ inches.
For ⅞-inch rivets, 2½ inches.
For ¾-inch rivets, 2¼ inches.
For ⅝-inch rivets, 2 inches.

The minimum thickness of bars shall be one-fortieth of the distance between connections for single lacing, and one-sixtieth for double lacing, but not less than five-sixteenths inch.

Lacing bars of compression members shall be so spaced that the L/r of the portion of the flange included between lacing bar connections will be not greater than 40, and not greater than two-thirds of the L/r of the member.

The angle between the lacing bars and the axis of the member shall be approximately 45 degrees for double lacing and 60 degrees for single lacing. If the distance between rivet lines in the flanges is more than 15 inches, and a bar with a single rivet in the connection is used, the lacing shall be double and riveted at the intersections. Lacing bars having at least two rivets in each end shall be used on flanges 5 inches or more in width.

Shapes of equal strength may be used instead of flats.

Net Section at Pin Holes

1519. In pin-connected riveted tension members, the net section across the pin hole shall be not less than 140 per cent and the net section back of the pin hole not less than 100 per cent of the net section of the body of the member.

Net Section of Riveted Tension Members

1520. In calculating the required section of riveted tension members, net sections shall be used in all cases and, in deducting rivet holes, the holes shall be taken as ⅛ inch larger than the nominal diameter of the rivet.

The net section shall be the least area which can be obtained by deducting from the gross sectional area, the area of holes cut by any straight or zigzag section across the member, counting the full area of the first hole and a fractional part of each succeeding hole, the fractional part being determined by the formula:

$$X = 1 - \frac{S^2}{4gh}, \text{ in which}$$

X = fraction of rivet hole to be deducted.
S = stagger or longitudinal spacing of rivet with respect to rivet on last gage line.
g = distance between gage lines, or transverse spacing.
h = diameter of rivet holes, or nominal diameter of rivet plus ⅛ inch.

Location of Pins

1521. Pins shall be so located with respect to the gravity axes of the members, as to reduce secondary stresses due to bending to a minimum.

Pin Plates

1522. Where necessary to give the required section or bearing area at pin holes, each segment of the member shall be reinforced by plates. One plate on each side shall be as wide as the outstanding flanges will permit. In the case of members composed of web plates and flange angles (with or without a cover plate) there shall be at least one pin plate covering the vertical legs of the flange angles. Pin plates shall contain enough rivets and be so connected as to transmit and distribute the bearing pressure uniformly over the full cross-section and to reduce the eccentricity in the segment to a minimum.

Pin-connected compression members shall be provided with hinge plates not less than ⅜ inch thick.

Forked Ends

1523. Forked ends on compression members will be permitted only where unavoidable. If forked ends are used, pin plates shall be provided to make the total sectional area of the jaws equal to twice the sectional area of the member. These plates shall be extended as far as necessary to carry the stress of the main member into the jaws.

Pins and Pin Nuts

1524. Pins shall be of sufficient length to secure a full bearing of all parts connected upon the turned body of the pin. They shall be secured in position by hexagonal chambered nuts or by hexagonal solid nuts with washers. If the pins are bored, through rods with cap washers may be used. Pin nuts shall be malleable castings or steel. They shall be secured by cotter pins in the screw ends or else the screw ends shall be long enough to permit burring the threads.

Members shall be held against lateral movement on the pins.

Bolts

1525. Bolted connections shall not be used unless specifically authorized. Bolts shall be unfinished or turned as specified and shall meet the requirements of Article 319. Bolts in tension shall have two nuts.

Upset Ends

1526. Bars and rods with screw ends shall be upset to provide a section at the root of the thread which will exceed the net section of the body of the member by at least 15 per cent.

Sleeve Nuts

1527. Sleeve nuts shall not be used.

Expansion

1528. Provision shall be made for expansion and contraction at the rate of 1¼ inches for every 100 feet. The expansion ends shall be secured against lateral movement.

Expansion Bearings

1529. Spans of less than 70 feet may be arranged to slide upon metal plates with smooth surfaces. Spans of 70 feet and greater shall be provided with rollers or rockers, or else with bronze sliding expansion bearings.

Bronze Sliding Expansion Bearings

1530. Bronze sliding plates shall be chamfered at the ends. They shall be held securely in position, usually by being inset into the metal of the pedestals and sole plates. Provision shall be made against any accumulation of dirt which will obstruct free movement of the span.

Fixed Bearings

1531. Fixed ends shall be firmly anchored.

Pedestals and Shoes

1532. Pedestals and shoes preferably shall be made of cast steel or structural steel. The difference in width between the top and bottom bearing surfaces shall not exceed twice the distance between them. For hinged bearings, this distance shall be measured from the center of the pin. In built pedestals and shoes, the web plates and angles connecting them to the base plate shall be not less than ⅝ inch thick. If the size of the pedestal permits, the webs shall be rigidly connected transversely. The minimum thickness of the metal in cast steel pedestals shall be one inch. Pedestals and shoes shall be so designed that the load will be distributed uniformly over the entire bearing. Spans of 70 feet and greater shall have hinged or pin bearings at both ends.

Rollers

1533. Expansion rollers shall be not less than 6 inches in diameter. They shall be connected by substantial side bars and shall be guided by gearing or other effectual means to prevent lateral movement, skewing and creeping. The rollers and bearing plates shall be protected from dirt and water as far as practicable, and the design shall be such that water will not be retained and that the roller nests may be inspected and cleaned easily.

Inclined Bearings

1534. For spans on an inclined grade and without hinged bearings, the sole plates shall be beveled so that the masonry surfaces and the sliding surfaces will be level.

Anchor Bolts

1535. Trusses, girders and I-beam spans shall be securely anchored to the substructure. Anchor bolts shall be swedged or threaded to secure a satisfactory grip upon the material used to embed them in the holes.

The following are the minimum requirements for each bearing:

For I-beam spans the outer beams shall be anchored at each end with two bolts 1-inch in diameter, set 10 inches in the masonry.

For trusses and girders:

Spans 50 feet in length or less, 2 bolts, 1-inch in diameter, set 10 inches in the masonry.
Spans 51 to 100 feet, 2 bolts, 1¼ inches in diameter, set 12 inches in the masonry.
Spans 101 to 150 feet, 2 bolts, 1½ inches in diameter, set 15 inches in the masonry.
Spans greater than 150 feet, 4 bolts, 1½ inches in diameter, set 15 inches in the masonry.

Anchor bolts subject to tension shall be designed to engage a mass of masonry which will provide a resistance equal to 1½ times the calculated uplift.

Name Plates

1536. Unless otherwise specified there shall be a name plate, showing in raised letters and figures the name of the manufacturer and the year of construction, bolted to the bridge near each end at a point convenient for inspection.

(XVI) FLOOR SYSTEM

Stiffness of Floor Members

1601. Floor members shall be designed with special reference to stiffness by making them as deep as economy or the limiting under-clearances will permit.

Stringers

1602. Stringers preferably shall be riveted between the floor beams.

Cross Frames

1603. In bridges with wooden floors and steel stringers, intermediate cross-frames (or diaphragms) shall be placed between stringers more than 20 feet long.

Floor Beams

1604. Floor beams preferably shall be at right angles to the trusses or main girders and shall be rigidly connected thereto. Usually floor-beam connections shall be located above the bottom chord and, in riveted work, the bottom lateral system shall engage both the bottom chord and the floor beam. In pin-connected trusses, if the floor beams are located below the bottom-chord pins, the vertical posts shall be extended below the pins to make a rigid connection to the floor beam.

End Floor Beams

1605. There shall be end floor beams in all square-ended truss and girder spans and preferably in skew spans. End floor beams for truss spans preferably shall be designed to permit the use of jacks for lifting the superstructure.

End floor beams shall be arranged to permit painting of the side of the beam adjacent to the abutment backwall.

End Panels

1606. In skew bridges without end floor beams, the end panel stringers shall be secured in correct position by end struts connected to the stringers and to the main trusses or girders. The end panel lateral bracing shall be attached to the main trusses or girders and also to the end struts. Adequate provision shall be made for the expansion movement of stringers.

End Connections of Floor Beams and Stringers

1607. The end connection angles of floor beams and stringers shall be not less than $\frac{3}{8}$ in. in finished thickness. Except in cases of special end floor beam details, each end connection for floor beams and stringers shall be made with two angles. The length of these angles shall be as great as the flanges will permit. Bracket or shelf angles which may be used to furnish support during erection shall not be considered in determining the number of rivets required to transmit end shear.

End connection details shall be designed with special care to provide clearance for the driving of field connection rivets.

Where timber stringers frame into floor beams, shelf angles with stiffeners shall be provided to carry the whole reaction. Shelf angles shall be not less than $\frac{7}{16}$ inch thick.

Any type of floor beam hanger which will permit the rotation or the longitudinal motion of the floor beam shall not be used.

Sidewalk Brackets

1608. Sidewalk brackets shall be connected in such a way that the bending stresses will be transferred directly to the floor beams.

Expansion Joints

1609. To provide for expansion and contraction movement, floor expansion joints shall be provided at the expansion ends of all spans and at other points where they may be necessary.

Apron plates, when used, shall be designed to bridge the joint and to prevent, so far as practicable, the accumulation of roadway débris upon the bridge seats. Preferably they shall be connected rigidly to the end floor beam.

(XVII) BRACING

Design of Bracing

1701. Bracing shall be composed of angles or other shapes and the connections shall be riveted.

If a double system of bracing is used, both systems may be considered effective simultaneously if the members meet the requirements both as tension and compression members. The members shall be riveted at their intersections.

Minimum Size of Angles

1702. The smallest angle used in bracing shall be 3 by 2½ inches. There shall be not less than three rivets in each end connection of the angles.

Lateral Bracing

1703. Bottom lateral bracing shall be provided in all spans except I-beam spans and deck plate girder spans of 50 feet or less. Bottom laterals shall be supported at their intersections by rigid hangers, if necessary, to prevent excessive deflection.

Top lateral bracing shall be provided in deck spans, and in through spans having sufficient head room.

The lateral bracing of compression chords preferably shall be as deep as the chords and effectively connected to both flanges.

Portal and Sway Bracing

1704. Through truss spans shall have portal bracing, preferably of the two plane or box type, rigidly connected to the end post and the top chord flanges, and as deep as the clearance will allow. If a single plane portal is used it shall be located preferably in the central transverse plane of the end posts, with diaphragms between the webs of the posts to provide for a distribution of the portal stresses. The portal bracing shall be designed to take the full end reaction of the top chord lateral system and the end posts shall be designed to transfer this reaction to the truss bearings.

Deck truss spans shall have sway bracing in the plane of the end posts and at all intermediate panel points. This bracing shall extend the full depth of the trusses below the floor system. The end sway bracing shall be proportioned to carry the entire upper lateral stress to the supports through the end posts of the truss.

Through truss spans shall have sway bracing at each intermediate panel point if the height of the trusses is such as to permit a depth of 5 feet or more for the bracing. When the height of the trusses will not permit of such depth, the top lateral struts shall be provided with knee braces. Top lateral struts shall be at least as deep as the top chord.

Deck Plate Girder Spans

1705. Deck plate girder spans shall be provided with cross frames at each end, proportioned to resist the lateral forces, and shall have intermediate cross frames at intervals not exceeding 20 feet. Cross frames shall be connected to the outstanding legs of the stiffener angles and to the girder flanges.

Half-Through Truss Spans

1706. The vertical truss members and the floor beam connections of half-through truss spans shall be proportioned to resist a lateral force, applied at the top chord panel points of the truss, determined by the following equation:

$R = 150\,(A + P)$ in which:
$R =$ lateral force in pounds.
$A =$ area of cross-section of the chord in square inches.
$P =$ panel length in feet.

This rigidity may be secured in part by extending one or both of the floor beam connection angles upward along the inside of the post and by providing a solid web in the post.

If outrigger brackets are used they shall be effectively connected to the floor beam.

Through Plate Girder Spans

1707. Through plate-girder spans shall be stiffened against lateral deformation by means of gusset plates, or knee braces with solid webs, attached to the stiffener angles and floor beams. These braces generally shall extend to the clearance line. If the unsupported length of the inclined edge of the gusset plate exceeds 60 times its thickness, the gusset plate shall have one or two stiffening angles riveted along its edge.

Bracing of Long Columns

1708. The bracing of long columns shall be designed to fix the column in both the lateral and the longitudinal directions, at or near the same point.

(XVIII) PLATE GIRDERS

Design of Plate Girders

1801. Plate girders shall be proportioned either by the moment of inertia of their net sections, including compression side; or by assuming that the flanges are concentrated at their centers of gravity. In the latter case, one-eighth of the gross section of the web, if the web is effectively spliced, may be considered as flange section. For girders having unusual sections, the moment of inertia method shall be used.

Flange Sections

1802. The flange angles shall form as large a part of the area of the flange as practicable. Side plates shall not be used except where flange angles exceeding ⅞ inch in thickness otherwise would be required.

The gross area of the compression flange shall be not less than the gross area of the tension flange.

Flange plates shall be of equal thickness, or shall decrease in thickness from the flange angles outward. No plate shall have a thickness greater than that of the flange angles.

If flange plates are used, at least one plate on the top flange shall extend the full length of the girder, except where the flange is to be covered with concrete. Any additional flange plates shall extend at least one foot beyond the theoretical end, and there shall be a sufficient number of rivets at each end of each plate to develop its full stress value before the end of the next outside plate is reached.

Thickness of Web Plates

1803. The thickness of web plates, except those to be encased in concrete, shall be not less than $\frac{1}{20}\sqrt{D}$, in which D is the distance in inches between flanges.

Flange Rivets

1804. The number of rivets connecting the flange angles to the web plate shall be sufficient to develop the increment of flange stress transmitted to the flange angles, combined with any load that is applied directly to the flange. For electric railways, one wheel load, when applied directly to the flange, shall be assumed to be distributed uniformly over a length of 3 feet.

Flange Splices

1805. Splices in flange parts shall not be used except by special permission of the Engineer. Not more than one part shall be spliced at the same cross-section. If practicable, splices shall be located at points where there is an excess of section. The net section of the splice shall exceed by 10 per cent the net section of the part spliced. Flange angle splices shall consist of two angles, one on each side of the girder.

Web Splices

1806. Web plates shall be spliced symmetrically by plates on each side. The splice shall be equal to the web in strength in both shear and moment. The splice plates for shear shall be of the full depth of the girder between flanges. In the splice, there shall be not less than two rows of rivets on each side of the joint.

End Stiffeners

1807. Over the end bearings of plate girders, there shall be stiffener angles, the outstanding legs of which shall extend as nearly as practicable to the outer edge of the flange angles. End stiffeners shall be proportioned for bearing on the outstanding legs of the flange angles, no allowance being made for the portions of the legs fitted to the fillets of the flange angles. End stiffeners shall be arranged, and there shall be a sufficient number of rivets in their connection to the web, to transmit the entire end reaction to the bearings. They shall not be crimped.

Intermediate Stiffeners

1808. The webs of plate girders shall be stiffened by angles not greater than:

(a) 6 feet;
(b) The depth of the web;
(c) The distance given by the formula

$$d = 100t\sqrt{\frac{24000}{S} - 1}, \text{ in which}$$

d = clear distance between stiffeners, in inches.
t = thickness of web, in inches.
S = unit shearing stress in the gross vertical section of the web due to dead load, and the live load increased as specified in Article 1301.

If the depth of the web between the flange angles, or between the side plates, if there are side plates, is less than 60 times the thickness of the web, intermediate stiffeners may be omitted.

Intermediate stiffener angles shall be placed at points of concentrated loading and shall be so designed as to transmit the reactions to the girder web. Such stiffeners shall not be crimped.

Intermediate stiffener angles shall be riveted in pairs to the web of the girder. The width of the outstanding leg shall not be more than 16 times its thickness, and not less than 2 inches plus one-thirtieth of the depth of the girder.

Ends of Through Girders

1809. The upper corners of through plate girders, where exposed, shall be rounded to a radius consistent with the size of the flange angles and the vertical height of the girder above the roadway. The first flange plate or a plate of the same width shall be bent around the curve and continued to the bottom of the girder. In a bridge consisting of two or more spans, only the corners at the extreme ends of the bridge need be so rounded unless the spans have girders of different heights. In such a case the higher girders shall have their top flanges curved down at the ends to meet the top corners of the girders in the adjacent spans.

Sole Plates

1810. Sole plates of plate girders shall have a thickness of not less than ¾ inch and not less than the thickness of the flange angles plus ⅛ inch. Preferably they shall not be longer than 18 inches.

Masonry Bearings

1811. Ends of girders on masonry shall be so supported on metal pedestals that the bottom flanges will be above the bridge seat, preferably not less than 6 inches.

Camber

1812. In general, camber will not be required in plate girders except for long spans or special conditions. When required, it shall be in the amount specified by the Engineer.

(XIX) TRUSSES

Main Features

1901. Preference will be given to trusses with single intersection web systems. Members shall be symmetrical about the central plane of the truss.

Trusses preferably shall have inclined end posts. Half-through trusses shall be of the riveted type. Laterally unsupported hip joints shall be avoided.

Top Chords and End Posts

1902. Top chords and end posts usually shall be made of two side segments with one cover plate, and with stay plates and lacing on the open

Bracing

2005. Towers shall be braced, both transversely and longitudinally, with stiff members having riveted connections. The sections of members of longitudinal bracing in each panel shall not be less than those of the members in corresponding panels of the transverse bracing.

Column splices shall be above and close to the panel points of the bracing.

Bottom Struts

2006. The bottom struts of viaduct towers shall be strong enough to slide the movable shoes with the structure unloaded, the coefficient of friction being assumed as 0.25. Provision for expansion of the tower bracing shall be made in the column bearings.

Depth of Girders

2007. The depths of girders in viaducts preferably shall be uniform.

Girder Connections and Bracing

2008. Girders of tower spans shall be fastened at each end to the tops of the columns or to the cross girders. Preferably there shall be a line of girders resting directly over the columns. One end of the girders between towers shall be riveted to the support, and there shall be an effective expansion bearing at the other end. No bracing or sway frame shall be common to abutting spans.

If girders are not supported directly on the columns, provision shall be made for the transmission of the longitudinal forces to the tower bracing.

Sole and Masonry Plates

2009. Sole plates, masonry plates, and cap plates shall be not less than ¾ inch thick.

Table of Moments, Shears and Floorbeam Reactions for H-20 Loading —One Lane

MOMENT IN THOUSANDS OF FOOT POUNDS—SHEARS AND REACTIONS IN THOUSANDS OF POUNDS

	Shear		*Moment*		*F.B. Reaction*	
Span	*L.L.*	*Impact*	*L.L.*	*Impact*	*L.L.*	*Impact*
5	32.0	12.3	40.0	15.4	32.0	11.9
6	32.0	12.2	48.0	18.3	32.0	11.7
7	32.0	12.1	56.0	21.2	32.0	11.5
8	32.0	12.0	64.0	24.1	32.0	11.3
9	32.0	11.9	72.0	26.9	32.0	11.2
10	32.0	11.9	80.0	29.6	32.0	11.0
11	32.0	11.8	88.0	32.3	32.0	10.9
12	32.0	11.7	96.0	35.0	32.0	10.7
13	32.0	11.6	104.0	37.7	32.0	10.6
14	32.0	11.5	112.0	40.3	32.0	10.5
15	32.5	11.6	120.0	42.9	32.5	10.5

Table of Moments, Shears and Floorbeam Reactions for H-20 Loading —One Lane—Continued

MOMENT IN THOUSANDS OF FOOT POUNDS—SHEARS AND REACTIONS IN THOUSANDS OF POUNDS

	Shear		*Moment*		*F.B. Reaction*	
Span	*L.L.*	*Impact*	*L.L.*	*Impact*	*L.L.*	*Impact*
16	33.0	11.7	128.0	45.4	33.0	10.5
17	33.4	11.8	136.0	47.9	33.4	10.5
18	33.8	11.8	144.0	50.3	33.8	10.5
19	34.1	11.8	152.0	52.8	34.1	10.5
20	34.4	11.9	160.0	55.2	34.4	10.4
21	34.7	11.9	168.0	57.5	34.7	10.4
22	34.9	11.9	176.0	59.9	34.9	10.3
23	35.1	11.9	184.0	62.2	35.1	10.3
24	35.3	11.9	192.0	64.4	35.3	10.2
25	35.5	11.8	200.0	66.7	35.5	10.1
26	35.7	11.8	208.0	68.9	35.7	10.1
27	35.9	11.8	216.9	71.3	35.9	10.0
28	36.0	11.8	226.8	74.1	36.0	9.9
29	36.1	11.7	236.7	76.9	36.1	9.9
30	36.3	11.7	246.6	79.6	36.3	9.8
31	36.4	11.7	256.5	82.2	36.6	9.8
32	36.5	11.6	266.5	84.9	36.9	9.8
33	36.6	11.6	276.4	87.5	37.2	9.7
34	36.7	11.5	286.3	90.0	37.4	9.7
35	36.8	11.5	296.2	92.6	37.7	9.7
36	36.9	11.5	306.2	95.1	37.9	9.6
37	37.0	11.4	316.1	97.6	38.1	9.6
38	37.1	11.4	326.1	100.0	38.3	9.5
39	37.1	11.3	336.0	102.4	38.5	9.5
40	37.2	11.3	346.0	104.8	38.7	9.4
41	37.3	11.2	355.9	107.2	38.9	9.4
42	37.3	11.2	365.9	109.5	39.0	9.3
43	37.4	11.1	375.8	111.8	39.2	9.3
44	37.5	11.1	385.8	114.1	39.4	9.2
45	38.0	11.2	395.7	116.4	40.6	9.4
46	38.6	11.3	405.7	118.6	41.7	9.6
47	39.2	11.4	415.7	120.8	42.8	9.8
48	39.7	11.5	425.6	123.0	43.9	9.9
49	40.2	11.5	435.6	125.2	44.9	10.1
50	40.6	11.6	445.6	127.3	45.9	10.2
51	41.1	11.7	455.5	129.4	46.9	10.3
52	41.5	11.7	465.5	131.5	47.8	10.4
53	42.0	11.8	475.5	133.6	48.6	10.5
54	42.4	11.8	485.5	135.6	49.5	10.6
55	42.8	11.9	495.4	137.6	50.3	10.7
56	43.1	11.9	505.4	139.6	51.1	10.8
57	43.5	12.0	515.4	141.6	51.8	10.8
58	43.9	12.0	525.4	143.5	52.6	10.9
59	44.3	12.0	535.3	145.5	53.4	11.0
60	44.7	12.1	545.3	147.4	54.1	11.0

Bracing

2005. Towers shall be braced, both transversely and longitudinally, with stiff members having riveted connections. The sections of members of longitudinal bracing in each panel shall not be less than those of the members in corresponding panels of the transverse bracing.

Column splices shall be above and close to the panel points of the bracing.

Bottom Struts

2006. The bottom struts of viaduct towers shall be strong enough to slide the movable shoes with the structure unloaded, the coefficient of friction being assumed as 0.25. Provision for expansion of the tower bracing shall be made in the column bearings.

Depth of Girders

2007. The depths of girders in viaducts preferably shall be uniform.

Girder Connections and Bracing

2008. Girders of tower spans shall be fastened at each end to the tops of the columns or to the cross girders. Preferably there shall be a line of girders resting directly over the columns. One end of the girders between towers shall be riveted to the support, and there shall be an effective expansion bearing at the other end. No bracing or sway frame shall be common to abutting spans.

If girders are not supported directly on the columns, provision shall be made for the transmission of the longitudinal forces to the tower bracing.

Sole and Masonry Plates

2009. Sole plates, masonry plates, and cap plates shall be not less than ¾ inch thick.

Table of Moments, Shears and Floorbeam Reactions for H-20 Loading —One Lane

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7	32.0	12.1	56.0	21.2	32.0	11.5
8	32.0	12.0	64.0	24.1	32.0	11.3
9	32.0	11.9	72.0	26.9	32.0	11.2
10	32.0	11.9	80.0	29.6	32.0	11.0
11	32.0	11.8	88.0	32.3	32.0	10.9
12	32.0	11.7	96.0	35.0	32.0	10.7
13	32.0	11.6	104.0	37.7	32.0	10.6
14	32.0	11.5	112.0	40.3	32.0	10.5
15	32.5	11.6	120.0	42.9	32.5	10.5

Table of Moments, Shears and Floorbeam Reactions for H-20 Loading —One Lane—Continued

MOMENT IN THOUSANDS OF FOOT POUNDS—SHEARS AND REACTIONS IN THOUSANDS OF POUNDS

	Shear		*Moment*		*F.B. Reaction*	
Span	*L.L.*	*Impact*	*L.L.*	*Impact*	*L.L.*	*Impact*
16	33.0	11.7	128.0	45.4	33.0	10.5
17	33.4	11.8	136.0	47.9	33.4	10.5
18	33.8	11.8	144.0	50.3	33.8	10.5
19	34.1	11.8	152.0	52.8	34.1	10.5
20	34.4	11.9	160.0	55.2	34.4	10.4
21	34.7	11.9	168.0	57.5	34.7	10.4
22	34.9	11.9	176.0	59.9	34.9	10.3
23	35.1	11.9	184.0	62.2	35.1	10.3
24	35.3	11.9	192.0	64.4	35.3	10.2
25	35.5	11.8	200.0	66.7	35.5	10.1
26	35.7	11.8	208.0	68.9	35.7	10.1
27	35.9	11.8	216.9	71.3	35.9	10.0
28	36.0	11.8	226.8	74.1	36.0	9.9
29	36.1	11.7	236.7	76.9	36.1	9.9
30	36.3	11.7	246.6	79.6	36.3	9.8
31	36.4	11.7	256.5	82.2	36.6	9.8
32	36.5	11.6	266.5	84.9	36.9	9.8
33	36.6	11.6	276.4	87.5	37.2	9.7
34	36.7	11.5	286.3	90.0	37.4	9.7
35	36.8	11.5	296.2	92.6	37.7	9.7
36	36.9	11.5	306.2	95.1	37.9	9.6
37	37.0	11.4	316.1	97.6	38.1	9.6
38	37.1	11.4	326.1	100.0	38.3	9.5
39	37.1	11.3	336.0	102.4	38.5	9.5
40	37.2	11.3	346.0	104.8	38.7	9.4
41	37.3	11.2	355.9	107.2	38.9	9.4
42	37.3	11.2	365.9	109.5	39.0	9.3
43	37.4	11.1	375.8	111.8	39.2	9.3
44	37.5	11.1	385.8	114.1	39.4	9.2
45	38.0	11.2	395.7	116.4	40.6	9.4
46	38.6	11.3	405.7	118.6	41.7	9.6
47	39.2	11.4	415.7	120.8	42.8	9.8
48	39.7	11.5	425.6	123.0	43.9	9.9
49	40.2	11.5	435.6	125.2	44.9	10.1
50	40.6	11.6	445.6	127.3	45.9	10.2
51	41.1	11.7	455.5	129.4	46.9	10.3
52	41.5	11.7	465.5	131.5	47.8	10.4
53	42.0	11.8	475.5	133.6	48.6	10.5
54	42.4	11.8	485.5	135.6	49.5	10.6
55	42.8	11.9	495.4	137.6	50.3	10.7
56	43.1	11.9	505.4	139.6	51.1	10.8
57	43.5	12.0	515.4	141.6	51.8	10.8
58	43.9	12.0	525.4	143.5	52.6	10.9
59	44.3	12.0	535.3	145.5	53.4	11.0
60	44.7	12.1	545.3	147.4	54.1	11.0

[13]SPECIFICATIONS FOR STEEL RAILWAY TURNTABLES

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INFORMATION TO BE GIVEN BIDDERS

1. Copy of contract form.
2. Will there be separate contracts for the different parts of the table?
3. Normal time for turning the table.
4. House for operator shall be built by whom?
5. Will the Railway Company furnish the deck and track material?
6. Type of center to be used.
7. Kind of power to be used.
8. Kind of fuel for internal combustion engine.

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[13] Adopted, Vol. 25, 1924, pp. 228, 1262.

9. Electric power service characteristics.
10. At what point will the Railway Company deliver power?
11. What are the conditions at the site?
12. Furnish plan showing the general dimensions necessary for designing the table.
13. Length of table.
14. Type of table.
15. Type of floor.
16. General dimensions of pit.
17. Shall the work be "Punched Work" or "Reamed Work"?
18. What size rivets shall be used?
19. What kind of shop paint will be approved?
20. Will the Railway Company erect the table?
21. Will the Railway Company furnish and apply field paint?
22. What kind of field paint will be approved?

Specifications which Apply

1. The current Specifications for Steel Railway Bridges and the current Specifications for Movable Railway Bridges, American Railway Engineering Association, shall apply except as otherwise specified herein.

(I) GENERAL FEATURES OF DESIGN

Types of Turntables

2. Turntables shall be of the following kinds:

(a) Balanced
(b) Three-point-support
    (1) Continuous
    (2) Non-continuous

Tables preferably shall be of the deck plate girder type. Through plate girder, pony truss, and through truss types may be used.

Length

3. The nominal length of the table is defined as the diameter of the pit; this diameter shall be a multiple of 10 feet.

The length shall be such that:

(a) For balanced tables, no part of the longest engine to be turned will project beyond the ends of the table when the engine, with tender empty, is balanced on the table.
(b) For three-point-support tables, no part of the longest engine to be turned will project beyond the ends of the table.

Clearances

4. The clearances shall be not less than those shown on the diagram, Fig. 1. The height of rail shall be assumed as 6 inches.

Power Operation

5. Tables 80 feet or more in length preferably shall be power operated.

(II) LOADS

Loads

6. The table shall be proportioned for the following loads:

(a) The dead load.
(b) The live load without impact.
(c) The force required to rotate the table.

The stresses due to these loads and forces shall be shown separately on the stress sheets.

Live Loads for Design

7. The minimum live load shall be that shown in Fig. 2 for the corresponding length of table, or that shown in Fig. 3. The loading that gives the larger stresses shall be used.

End floor beams, end trucks, and parts subject to similar reactions shall be proportioned for an axle load of 70,000 pounds in addition to the specified live load, and superimposed in the most effective position.

(III) UNIT STRESSES AND PROPORTIONING OF PARTS

Unit Stresses

8. The unit stresses shall be as given in the Specifications named in Section 1, except for the parts which determine the deflection at the ends of balanced tables. Such parts shall be so proportioned that the unit stresses will not exceed the following:

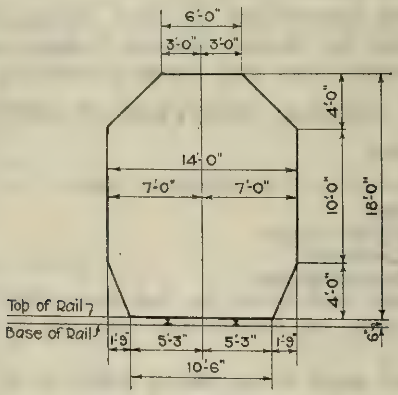
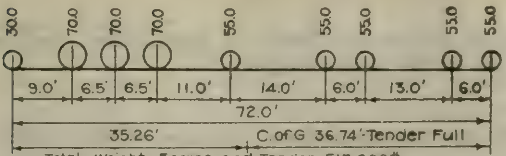


FIG. 1

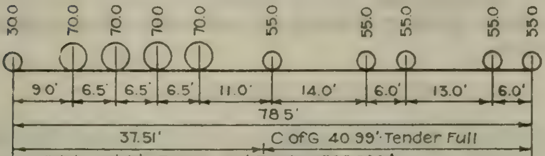
	Pounds per sq. in
Axial tension	10,000
Axial compression	9,500—30 l/r
l = length of member in inches.	
r = least radius of gyration of member in inches.	
Tension in extreme fibers of rolled shapes, built sections, and girders, net section	10,000
Tension in extreme fibers of pins	15,000
Shear in plate girder webs, gross section	6,500
Shear in power driven rivets and pins	7,500
Bearing on power driven rivets, pins, outstanding legs of stiffener angles, and other steel parts in contact	15,000

The above-mentioned values for shear and bearing shall be reduced 25 per cent for countersunk rivets.



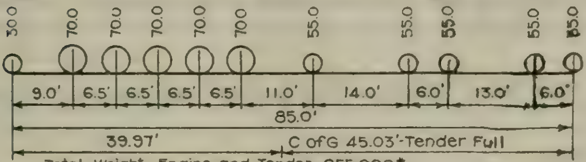
Total Weight - Engine and Tender - 515,000#

80 FT. TABLE



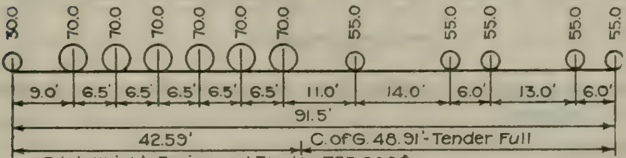
Total Weight - Engine and Tender - 585,000#

90 FT. TABLE



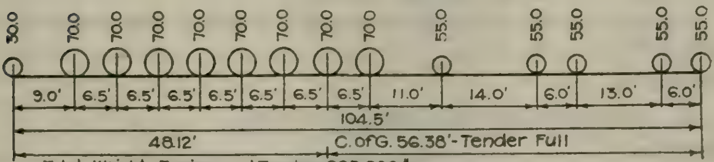
Total Weight - Engine and Tender - 655,000#

100 FT. TABLE



Total Weight - Engine and Tender - 725,000#

110 FT. TABLE



Total Weight - Engine and Tender - 865,000#

120 FT. TABLE

FIG. 2

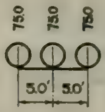


FIG. 3

Flange Areas

9. The gross area of compression flanges of plate girders shall not be less than the gross area of the tension flanges.

Deflection

10. Balanced tables shall be so designed that the deflection due to live load will not exceed one-half inch for 80-ft. tables and one and one-quarter inches for 120-ft. tables. For tables of other lengths, the deflections shall be in proportion to those given.

In three-point-support tables, stiffness is not essential; rather a degree of flexibility is desirable.

(IV) DETAILS OF DESIGN

Bracing

11. Horizontal bracing shall be provided to permit turning the table by means of power applied at one end. There shall be both top and bottom lateral systems where practicable.

In balanced tables of the deck plate girder type, bracing to prevent warp is essential.

Inspection

12. Tables shall be so designed as to facilitate inspection and permit making repairs.

Protection of Parts

13. The center, center girders, and machinery shall be protected, preferably by metal housing, against the accumulation of water, cinders, and dirt.

(V) CENTER

Type

14. The center may be of either the roller or the disc type, as determined by the Engineer.

General Features

15. The point of application of the applied load shall be as nearly as practicable in the vertical through the center.

The entire center unit shall be as nearly dustproof and waterproof as practicable.

Adjustment

16. Adjustment for height shall be provided.

Inspection

17. The center shall be so designed as to be readily taken out and to facilitate taking apart for inspection, repairing and replacement of parts.

Materials

18. Rotating parts shall be of special materials, and their rolling and sliding surfaces shall be highly finished.

Cast iron shall be used for minor parts only.

Special materials used in the center, which are not covered by the Specifications named in Section 1, shall be in accordance with the Specifications of the American Society for Testing Materials, with the current revisions thereof.

(VI) END TRUCKS

General Features

19. The end trucks shall be of substantial construction, and braced to hold the axles of the wheels in radial lines over the circle-rail.

Each truck shall have at least two wheels at each main girder bearing.

The loads transmitted to the wheels shall be equalized.

The wheels shall not be flanged.

The wheels shall be of as large diameter as feasible.

On account of the impact of the live load, the elasticity of the parts immediately over the circle-rail shall be given consideration.

Wheels and Axles

20. The wheels and axles may be cast integrally from open-hearth steel, or the wheels may be rolled from open-hearth or Bessemer steel and mounted on open-hearth steel axles under heavy pressure.

Bearing Boxes

21. The bearing boxes shall be of cast steel, and provided with removable phosphor bronze bushings or bearings of other type, as determined by the Engineer.

Bearing boxes shall be compact, provided with lids which can be readily opened, and of such construction as will prevent the entrance of water and dirt.

(VII) PIT AND TRACKS

Circle-Rail

22. The circle-rail shall be of a section not less than the heaviest standard rail used by the Railway Company, and preferably not less than 120 lb. per yard.

In the design, consideration shall be given to drainage, adjustment of elevation, and curvature of circle-rail.

The top of the circle-rail shall be in a horizontal plane throughout its entire length.

Radial Tracks

23. The ends of the rails in the radial tracks shall be held securely in line and elevation. The top of rail of all radial tracks shall be at the same elevation as the top of rail on the end of the table with the end wheels bearing.

Radial track rails ending at the circle-wall shall be full length and anchored securely to prevent longitudinal movement.

Where wood supports are used for the ends of the rails in radial tracks, steel bearing plates shall be provided.

Rails on the Table

24. The rails on the table shall be held in line and elevation and anchored to prevent longitudinal movement. Steel bearing plates shall be provided throughout.

The rails at the ends of the table shall be full length.

Inspection Pits

25. Inspection pits in the circle-wall shall be provided.

[9]CONTRACTING FOR STEEL RAILWAY BRIDGES

It is recommended that railway companies:

(1) Furnish general detailed plans and specifications of structural work to bidders, complete enough to show the exact character of the work. If such plans cannot be furnished, the alternative should be full specifications, accompanied by outline plans and complete information concerning the work.

(2) Invite bids on a pound price basis. If desired, alternate bids may be asked for the work, f.o.b. cars, and for the work erected. A lump sum bid is inadmissible unless general detailed plans and specifications are furnished.

(3) Invite bids for as large groups of bridges as can be defined consistently with the first recommendation. When necessary to anticipate future requirements, the railway company need not submit designs if the nature of the work is known to the bidder by reason of similar work previously performed by him for the railway, or if designs of similar structures are submitted to the bidders.

(4) Erect bridges with their own forces on lines where traffic is to be maintained. On small railways where suitably organized and equipped forces for such work may not be justified, the large bridges, and in some cases all bridges, may be erected by contract.

(5) Furnish and lay the floor timber in all cases.

[10]INSTRUCTIONS FOR THE MILL INSPECTION OF STRUCTURAL STEEL

(1) Study the contract and specifications and secure such information concerning the proposed structure as will permit a full understanding of the use to be made of the various items of the order.

(2) Secure copies of the mill orders, shipping directions and other information concerning the material to be inspected.

(3) Attend promptly when notified of the rolling of material and so conduct the inspection and tests as not to interfere unnecessarily with the operations of the mill.

(4) Have the test specimens prepared and properly stamped with the melt numbers by the manufacturer. Observe the selection and stamping of specimens and verify the melt numbers when practicable.

(5) Attend and supervise the making of tensile, bending and drifting tests. Make sure that the testing machines are properly handled and that the specified speed of pulling is not exceeded. Note the behavior of the metal and check and record the results of the tests.

(6) Select the bars or other members for full-size tests as specified. Supervise such tests and check and record their results.

(7) Secure from the manufacturer records of the chemical analyses of the melts and accept only those in which the specified contents of impurities are not exceeded.

(8) Secure pieces of the test ingots and test specimens and have check analyses made outside of the manufacturers' laboratory when the analyses furnished by the manufacturer are erratic or for any other reason appear to be incorrect.

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[9] Adopted, Vol. 7, 1906, pp. 184, 263, 264; Vol. 11, Part 1, 1910, pp. 115, 160.
[10] Adopted, Vol. 14, 1913, pp. 86, 87, 1049-1050.

(9) Examine each piece of finished material for surface defects before shipment, requiring the material to be handled in a manner that will permit the examination to be thorough and complete. This inspection should detect evidence of excessive gagging or other injury due to cold straightening.

(10) Report promptly the shipment of any material from the mill, whose surface inspection has been waived. Such material should be examined by the shop inspector.

(11) Verify the section of all material by measurements and by weight.

(12) Study the operations of the plant and become familiar with the various processes of manufacture.

Cultivate the acquaintance of the mill employees and become familiar with their work so as to have direct knowledge of the mill practice and determine as well as the circumstances permit the correctness of the mill practice in so far as it is covered by the specifications.

(13) Record all tests and analyses on the forms provided.

(14) Keep informed as to the progress of the work in the shop and endeavor to secure the shipment of material at such times and in such order as to avoid delay in the fabrication.

(15) Secure copies of the shipping lists and compare them with the orders and make regular statements of the material that has been rolled and shipped.

(16) Make reports weekly or as may be directed, submitting complete records of tests, analyses and shipments and such other information as may be required.

[11]INSTRUCTIONS FOR THE INSPECTION OF THE FABRICATION OF STEEL BRIDGES

(1) Acquire a full knowledge of the conditions of the contract, such as the time of delivery, the railway company's actual need of the work, the desired order of shipment, and any special features in connection with the delivery, such as the position of the girders or truss members on cars at the bridge site.

(2) Study in advance the plans and specifications and see that all provisions thereof are complied with. These instructions are not to be construed as altering the specifications in any way.

(3) Endeavor to maintain pleasant relations with foremen and workmen; and by fairness, decisiveness and good sense, interest them in the successful completion of the work.

(4) Attend constantly to the work, making inspection during the progress of the work in the shop, striving to keep up with the output in order that errors may be corrected before the work leaves the shop.

Conduct the inspection so as not to interfere unnecessarily with the routine operations of the shop.

(5) When unusual circumstances require an explanation of the plans or some variation from the specified procedure, take the necessary action promptly.

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[11] Adopted, Vol. 14, 1913, pp. 87-89, 1050-1053; Vol. 15, 1914, pp. 410, 411, 1058.

(6) Study the field connections, paying particular attention to clearances and making notations on the drawings so that they may be checked rapidly.

(7) Check all bevels and field rivet holes.

(8) Give careful attention to the quality of the workmanship, the condition of the plain material, accuracy of punching, care in assembling, alinement of rivets, tightness of rivets, accuracy of finishing of machined joints, painting and general finish.

(9) Make sure that reamed holes are truly cylindrical and that drillings are not allowed to remain between assembled parts.

(10) Watch for bends, kinks and twists in the finished members and make certain that when leaving the shop members are in proper condition for erection.

(11) Make sure that the webs of girders do not project beyond the flange angles and that the depth of web below the flange angles complies with the specification.

(12) Allow only the material rolled and accepted for the work to be used therein.

(13) Have the fabricated material shipped in the correct order for erection and in accordance with instructions, as far as practicable.

(14) Measure the width of each column and the lengths of all girders between columns when they are to be placed consecutively in a long row so as to insure that the columns and girders will not "build out" in erection so as to exceed the calculated length.

(15) Check "rights" and "lefts" and make sure that the proper number of each is shipped.

(16) Check base plates of girders before riveting and make sure that the bevel is not reversed.

(17) Check the space provided for driving field rivets, allowing sufficient space for the pneumatic riveter.

(18) Examine field connections after riveting to insure proper fitting and ease of erection.

(19) Make sure that shop splices are properly fitted and that matched and milled surfaces to transmit bearing are in close contact during riveting as specified.

(20) Examine and measure bored pinholes carefully to insure proper position, dimension, spacing and smoothness of finish.

(21) Measure the spacing center to center of the end connections for sections of I-beam floors or any similar construction in which the calculated spacing is liable to be exceeded because of the tendency of such work to "grow" as it is assembled.

(22) Make sure that stringers connecting to floor beams beneath the flange have sufficient clearance to care for their possible over-run in depth.

(23) Have the assembling of trusses and girder spans required by the specifications carefully done and in any case insure the accuracy of field connections. If a large number of duplicate parts are to be made, the number of parts to be assembled should be governed by the workmanship. If errors are found, a sufficient number of parts should be assembled to make it reasonably certain that such errors have been eliminated.

(24) Secure match-marking diagrams for work which has been assembled and reamed and make sure that the match marks are plainly visible.

(25) Have proper camber blocking used in assembling trusses and secure the desired camber before the reaming is done.

(26) Require that all treads and supports for the drums of draw spans be carefully leveled with an instrument.

(27) Study carefully the machine details and discriminate between those dimensions which must be exact and those in which slight variations are permissible.

Determine in advance the desired accuracy of fits for bolts or keys and similar parts and make sure such accuracy is attained.

(28) Examine castings carefully for blowholes and other imperfections and discriminate between such defects as are unimportant and those which render the castings unfit for use.

(29) Make sure that bushings, collars and similar parts are held securely in place.

(30) Make sure that all drum wheels, expansion rollers, turntable rollers and similar parts are exact in size, so as to carry equally the loads which may be placed upon them.

(31) Ascertain in advance that the paint provided complies with specifications. Watch carefully the painting directions and make sure that paint is properly applied and only where intended.

(32) Verify all shop marks and make sure that they are legible as well as correct.

(33) Have important members so loaded as to be headed in the right direction upon arrival at the site of the work.

(34) Try a few countersunk head bolts in the holes where they are to be used to insure a proper fit.

(35) Make sure that small pieces are bolted in place for shipment as shown on the plans and that other small parts are properly boxed or otherwise secured against loss.

(36) Make sure that rivets, tie rods, anchor bolts and miscellaneous parts are shipped so as to avoid delay in erection.

(37) Examine the field rivets to insure that they are free from fins or other defects.

(38) Exercise special care in the examination of all movable structures and particularly their moving parts.

(39) Make reports weekly or as directed, exhibiting carefully and concisely the actual conditions.

(40) Observe carefully and report such unusual difficulties as may be encountered and the means adopted in overcoming them and endeavor by a study of the details or other means to make recommendations which will prevent their recurrence in future work.

(41) Check every finished member against the drawings for its general dimensions and for the section of each piece of material forming a component part of the member.

(42) Attend the weighing of material whenever practicable, especially that purchased on weight basis. Check the accuracy of the scales with test weights or by other sufficient means.

[12]INSTRUCTIONS FOR THE INSPECTION OF BRIDGE ERECTION

(1) Study and observe the plans and specifications for steel construction. Study the masonry plans and check the masonry as built with the steel plans.

(2) Familiarize yourself with the local conditions affecting erection. Make the acquaintance of the principal men engaged upon the work and of local residents whose interests may be affected thereby.

(3) Obtain and study carefully the employees' timetable and be well posted concerning the time and relative importance of regular and extra trains. Acquaint yourself with all special traffic arrangements made because of the work in hand.

(4) Secure full information concerning the condition of the work in the bridge shop and the probable dates of shipment.

(5) Obtain reports of any uncompleted or erroneous work that must be attended to after arrival of the material in the field.

(6) Study the erection program in order to avoid delays and be able to recommend some other procedure in an emergency.

(7) Endeavor to have full preparations made before disturbing the track so that the erection may proceed rapidly and the period of such disturbance be made a minimum.

(8) Keep a record of the arrival of all materials. The contractor's record should be sufficient if available. Strive to anticipate any shortage of material and use all available facilities to hasten delivery of the needed parts.

(9) Study the progress of the work and determine whether it is likely to be completed in the time allotted. If not, endeavor to secure such additions to the force and equipment as will insure such completion.

(10) Make a daily record of the force employed and the distribution of labor, in a way that will assist in following paragraphs 9 and 23.

(11) Exercise a constant supervision of any temporary structure or falsework and make soundings if necessary with the purpose of discovering any evidence of failure or lack of safety and having it corrected before damage is done. Examine erection equipment with a view to its safety and adequacy.

(12) Be constantly on hand when work is in progress and note any damage to the metal, failure to conform to the specifications, or any especial difficulty is assembling.

(13) Make sure that each member of the structure is placed in its proper position. If match marks are used, examine them with care.

Endeavor to have the several members assembled in such order that no unsatisfactory makeshifts need be resorted to in getting some minor member in place.

(14) Prevent any abuse or rough usage of the material. Bending, straining and heavy pounding with sledges are included in such abuse.

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[12] Adopted, Vol. 14, 1913, pp. 90, 91, 1053-1057.

(15) Watch carefully the use of fillers, washers and threaded members to see that they are neither omitted nor misused.

(16) Make certain that all parts of the structure are properly alined and that the required camber exists before riveting. It is possible for a structure to be badly distorted, although the rivet holes are well filled with bolts.

(17) Watch the heating of rivets to prevent underheating or overheating and to make sure that scale is removed.

Examine and test carefully all field-driven rivets and have any that are loose or imperfect replaced.

Have cut out and replaced all rivets, whether shop-driven or field-driven, that may be loosened during erection and riveting.

Prevent injury to metal while removing rivets.

(18) Present to the contractor at once for his attention any violation of the specifications or contract, and secure a correction or refer the matter to the proper authorities as soon as possible.

(19) Keep informed concerning the use of Company material and work trains and assist in procuring such material and trains when needed, and preserve a record thereof.

(20) Secure a match-marking diagram of any old structure to be removed which it is desired to re-erect and see that each part of such structure is properly marked in accordance therewith. Make a record of the manner of cutting the old structure apart and report any damage to the members of the old structure. Indicate by sketches or otherwise such repairs or replacements as will be found necessary in re-erection.

(21) Secure photographic records of progress and the important features of the work wherever practicable.

(22) Make a record of all flagging of trains, whether performed for the benefit of the contractor or otherwise, delay to trains, personal injuries and accidents of every kind.

(23) Make reports as directed, showing the progress of the work, the size of the force and the equipment in use.

Make a final report showing the cost of labor of erection per ton of material erected, the cost of labor per rivet in riveting, the cost of correcting errors in design and fabrication and commenting on the design and details; and give such other information as may be useful in planning similar work.

[1]CLASSIFICATION OF RAILWAY BRIDGES

(1) The classification of a bridge, as herein determined, is based on the heaviest moving load which may be operated over it in regular service for a limited time without subjecting it to such severe stresses, vibration, or wear of parts as seriously to impair its safety or serviceability.

(2) Iron and steel bridges shall be classified according to their rated carrying capacity as determined by the "Rules and Unit Stresses for Rating Existing Bridges."

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[1] Adopted, Vol. 25, 1924, pp. 228, 1262.

Division of Subject

(3) The work of classifying bridges consists of three steps:

(A) The determination of the capacity and rating of the bridges.

(B) The determination in corresponding terms of the effect and rating of each type and size of engine or other equipment used, in order that the territorial operating limits of each class of equipment may be assigned.

(C) The presentation of such data in form convenient for the operating personnel.

(A) RATING OF BRIDGES

Plans and Records

(a) Complete plans and records of each bridge shall be kept on file. Where no plans exist, field measurements shall be made and record plans prepared.

Bridge Sketches

(b) For ready reference, a sketch, or line diagram, of each bridge shall be prepared.

Record of Bridge Material

(c) The records shall show the material of which each bridge is composed. If necessary, the character of the material shall be determined from small specimens obtained in the field.

Assignment of Ratings

(d) Each bridge shall be calculated on the basis of the rating rules and specification loading in effect. The strength of each member, including connections and other details, shall be determined and the capacity of the bridge ascertained. The bridge shall then be given a rating corresponding to the rating of its weakest member.

Filing of Calculations

(e) The calculations shall be made in permanent form and filed for future reference.

Bridge Lists

(f) Lists of all bridges shall be prepared, showing for each bridge the identifying number or name, location, lengths and number of spans, type, number of tracks carried, material of which composed, date built, and capacity.

(B) RATING OF EQUIPMENT

Line Diagrams of Engines

(a) A line diagram of each engine shall be obtained and filed for reference. Such diagram shall show the axle loads and wheel spacing of the engine and tender, and the distance between the tender and the following engine when double-headed.

Moments and Shears

(b) The effect of each engine with its train load shall be ascertained by calculating the bending moments and shears. The calculations shall be based on an arrangement of loads similar to that used in the specifications; that is, if the specification loading provides for double-heading, the calculations shall be made on that basis.

Relation of Loads to Specification Loading

(c) For each span length for which moments and shears are determined, the effect of the load in terms of the specification loading shall be obtained.

Engine Rating

(d) The rating of the engine for operating purposes shall be expressed in terms of the engine for which the bridges are rated, and for that span length on which it produces its maximum effect.

List of Engine Ratings

(e) The rating of an engine may be lower on a particular bridge than its rating for operating purposes if its rating for the span length of that bridge is lower than for the span length on which it produces its maximum effect. For that reason a list of engines should be prepared, giving for each engine its number, class, type, total weight, rating for operating purposes, and rating for each span length.

(C) FORM OF PRESENTATION

Common Standard for Rating

(a) Following the procedure outlined will result in assigning to each bridge and to each engine a rating based on a common standard.

Cooper Series as the Common Standard

(b) The long use of the Cooper series as a standard of railroad bridge loading has already imparted to the operating personnel the significance of an operating condition involving engine loadings expressed in such terms. For this reason the Cooper series is adopted as the common standard.

Form for Use of Operating Department

(c) The ratings of the various lines shall be shown by means of a diagrammatic map, or arranged geographically in a table, or both; the rating of each engine shall be listed.

Special Cases

(d) Special conditions involving particular bridges on a line or the operation of special engines in certain territories, may be covered by the use of the asterisk or other symbols calling attention to exceptions to a general rule.

Rating of Foreign Engines

(e) Frequently questions are raised in regard to the movement of foreign engines over a line. The approximate ratings of such engines can readily be determined, if similar engines have previously been rated.

[14]RULES AND UNIT STRESSES FOR RATING EXISTING BRIDGES

(1) In fixing the carrying capacity of any bridge under traffic, its location, design, details, material, workmanship, behavior, and physical condition must be taken into account.

(2) Before recalculating an existing bridge, a careful inspection should be made to determine:

(a) Whether the actual sections and details conform to the drawings.

(b) The loss of metal due to corrosion and wear. This determination should be made by caliper measurements, after thorough removal of scale.

(c) The general physical condition. Defects such as loose rivets, worn pins, crooked or damaged members, cracked metal, etc., should be carefully noted.

Particular attention should be given to the position of the track with respect to center line of the bridge, and to undesirable details, such as forked ends of compression members, eccentricity in riveted joints and connections, unequal stress in tension members, etc.

(3) In recalculating bridges for increased loading, the equipment in actual use, or which it is proposed to use, shall be taken for determining the live load stresses. Where the design or details are such as to cause eccentric or unusual secondary stresses, these stresses shall be taken into account. It is recommended that stresses in members subject to marked secondary effects be determined by strain gage measurements.

(4) In spans exceeding 150 feet in length, and in viaduct towers, the effect of lateral (or wind) force shall be taken into account. The lateral force shall consist of a moving load equal to 15 lb. per square foot on the vertical projection of the structure on a plane parallel with its axis, and a moving load of 400 lb. per linear foot applied 8 ft. above the base of rail.

(5) On curves, the centrifugal force, based on actual speed of operation, and assumed to act 6 ft. above the base of rail, shall be taken into account.

(6) Where speeds may exceed 15 miles per hour, the dynamic increment of the live load shall be added to the maximum computed live load stresses and shall be determined by the formula

$$I = S \frac{300}{300 + \frac{L^2}{100}}$$

In which I = impact or dynamic increment to be added to the live load stress.

S = computed maximum live load stress.

L = the length in feet of the portion of the span which is loaded to product maximum stress in the member.

Where maximum live load stress is produced by heavy cars or electric locomotives, impact stresses shall be taken as one-half of those given by the formula above.

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[14] Adopted, Vol. 22, 1921, pp. 379, 1008.

(7) If a bridge is so located that speeds are definitely limited, or where absolute control of speed can be secured, 50 per cent of the impact given by the above formula shall be used when the speed is between 10 and 15 miles per hour, and 25 per cent when the speed is less than 10 miles per hour. If the bridge is located where the locomotive must be started, the speed increased, or the brakes applied, full impact shall be used in the calculations.

(8) Impact shall be added to stresses produced by centrifugal force, but not to those produced by lateral forces.

(9) For bridges on curves, and at other places where tracks are off center, consideration shall be given to the increased load carried by any truss, girder, or floor member due to the eccentricity of the load.

(10) The limiting stresses resulting from the loads and forces mentioned in the preceding articles, in combination with the actual dead load, shall not exceed the following, in pounds per square inch:

	Open-Hearth Steel	*Wrought Iron and Bessemer Steel*
Axial tension (net section)	26000	22000
Axial compression (gross section)	$24000-80\frac{l}{r}$	$21000-70\frac{l}{r}$
but not to exceed	20000	17000
l = length of the member in inches.		
r = least radius of gyration of the member in inches.		
Tension in extreme fibers of rolled shapes (except rolled beams), built sections and girders (net section)	26000	22000
Tension in extreme fibers of rolled beams (net section)	24000	20000
Compression in flanges of plate girders and I-beams (gross section)	$26000-300\frac{l}{b}$	$22000-250\frac{l}{b}$
but not to exceed	24000	21000
l = length in inches of the unsupported flange, between lateral connections or knee braces.		
b = flange width in inches.		
Tension in extreme fibers of pins (figured by assuming stresses concentrated at centers of bearings)	50000	40000
If the members are packed closely on the pin, the bending stress need not be considered unless the tension in extreme fiber exceeds 60000 lb. per sq. in. for open-hearth steel, or 50000 lb. per sq. in. for wrought iron and Bessemer steel.		
Shear in plate girder webs and rolled beams (gross section)	18000	15000
Shear in rivets and pins	22000	19000
Bearing on rivets, pins, outstanding legs of stiffener angles, and other steel parts in contact	44000	38000
The above-mentioned values for shear and bearing shall be reduced 20 per cent for countersunk rivets, floor connection rivets, and turned bolts.		

(11) In members subject to stresses produced by a combination of dead load, live load, impact, centrifugal force, and eccentric application of dead and live load, with lateral forces, or bending due to lateral action, unit stresses 25 per cent greater than those given in Article 10 may be allowed; but, in such cases, the unit stresses due wholly to dead load, live load, impact, centrifugal force, and eccentric application of dead and live load shall not exceed those given therein.

(12) In hangers having an unequal distribution of load, and in hangers or hip verticals consisting of a single member, consideration should be given to the necessity for reducing the allowable unit stress to meet this condition.

(13) Stresses in plate girders shall be computed either by the moment of inertia of their net sections; or by assuming that the flanges are concentrated at their centers of gravity. In the latter case, one-eighth of the gross section of the web, if continuous or properly spliced, may be used as flange section. For girders having unusual sections, the moment of inertia method shall be used.

(14) When the stresses exceed the foregoing limits, or when the design or physical condition makes it necessary, the structure shall be strengthened or renewed. When these limits are closely approached, or when the physical condition of the structure is not good, it shall be kept under close inspection as long as it is continued in service.

[15]COLUMN TESTS

The conclusions that seem warranted from the tests so far made in the proposed series are:

(1) Columns in which batten plates are substituted for lacing bars will not develop the full strength of the section and should not be used.

(2) The specimen tensile tests on which material is ordered and accepted afford no proper criterion for the strength of a column.

(3) A column designed so that it fails as a whole and not by reason of local weakness will have an ultimate strength of which the compressive yield point of the material of which it is made up is an index, since the higher this yield point is, the stronger will be the column.

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[15] Adopted, Vol. 21, 1920, pp. 489, 1398.

COMMITTEE XVI

ECONOMICS OF RAILWAY LOCATION

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[1]ECONOMICS OF RAILWAY LOCATION

(A) GENERAL

(1) Location

A line is located when its position is fixed horizontally and vertically.

(2) Economic Plant

Locating a railway means designing an economical plant for handling a given traffic. The economical plant for a given quantity and class of traffic may not be the economical plant for a greater or less quantity of traffic or for traffic of a different class. It is considered good practice to discount the future, within reasonable limits, provided the necessary funds are available.

(3) General Formula for Economic Value

The most general formula for the economic value of a location is:

$$\frac{R-E}{C}=p \qquad \text{.......................................}(1)$$

where $R=$ Annual revenue (receipts from operation);
$E=$ Annual expense of operation including depreciation and taxes;
$C=$ Capital invested (cost of construction);
$p=$ Percentage of income on investment.

(4) Special Formula for Economic Value

The following equation may be used in certain cases, especially where the annual revenue, known or unknown, is constant:

$$R-(E+I)=P \qquad \text{...............................}(2)$$

where $I=$ Amount of interest on cost of construction;
$P=$ Amount of profit (net corporate income).

When the revenue is constant the condition of equation (*2*) is that the sum of operating expenses plus interest on cost of construction shall be a minimum. The equation is convenient in many cases, but does not indicate the proportion of profit to investment. Care should be taken not to use too low a rate of interest. The ratio of profit to investment should be considered.

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[1] Adopted, Vol. 11, Part 1, 1911, pp. 631, 715; 647, 731; 666, 733; Vol. 16, 1915, pp. 138, 1067; 104, 1078; Vol. 21, 1920, pp. 305, 1382; Vol. 22, 1921, pp. 567, 1042; Vol. 24, 1923, pp. 260, 1148; Vol. 28, 1927, pp. 786, 1326.

(B) PRIMARY GOVERNING FEATURES

(5) Traffic

In order to make a location on an economic basis, the Engineer must know, or make a reasonable assumption of, the amount, direction of movement, and class of traffic which the railway will be called upon to handle, and the probable cost of operation. He must also consider variations in the amount and character of traffic that may be occasioned by changes in line, gradients or other features of location.

(6) Engine Districts

(a) LENGTH OF DISTRICT.—The engine district should be sufficiently long to obviate constructive mileage and short enough to enable the maximum slow freight train to make the run within the hours of service required.

(b) EXTENSION OF ENGINE RUNS.—Consideration should be given to the extension of engine runs over two or more service districts and provision should be made therefor in the determination of engine service limits.

(c) TERMINAL POINTS.—One of the necessary requisites for a terminal point is a suitable water supply for locomotives and for domestic use. It is desirable, where possible, that terminal points should be located on minor summits.

(7) Ruling Gradients

In deciding upon the ruling gradient for an engine district, due consideration should be given to the following:

(a) The necessity and cost of breaking up trains, where the rate of ruling grade on adjoining districts varies.

(b) The possibility of utilizing different types or sizes of motive power.

(c) The balance between steep gradients and shorter distance, and lower rates of gradient and increased distance and curvature.

(d) The time element of increased distance.

(e) The loss of time at meeting points—especially on crowded single track lines.

(f) The fact that a reduction of the rate of ruling gradient may have no effect on increasing the tonnage of passenger trains and very little effect on local and fast freights.

(g) The possibility of future revisions—and the utilization of the maximum amount of original work of construction.

(h) The possibility of extending engine runs over two or more service districts.

(8) Temporary Construction to Lessen First Cost

(a) PROVISION FOR GROWTH IN TRAFFIC.—In the construction of a line where the contemplated immediate traffic is small and the future traffic large, sharp curvature and steep temporary gradients, so situated as to be capable of reduction when justified by the traffic, may be advantageously introduced; a line being thus constructed which will provide for immediate requirements and which can be improved for future requirements at a reasonable expense.

Before deciding upon such temporary expedients, care should be taken to compare the cost of the work ultimately to be abandoned with the interest saved on the extra cost of construction that would have been necessary to construct a line on the final location during that period in which the more expensive construction would appear uneconomical.

(b) LOCATION OF STATIONS.—In the construction of temporary lines due consideration must be given to the location of stations, and these should not be located on portions of the line where revisions are contemplated, owing to the fact that if a receiving and delivery point for local traffic is once established, opposition from the public may prevent its removal.

(c) TERMINAL REQUIREMENTS.—In the matter of terminal property the future requirements should be estimated for a longer period than is justified for the line between terminals.

(9) Momentum Gradients

(a) MAXIMUM LIMITS.—Momentum gradients, not exceeding that over which a locomotive loaded for the ruling gradient can handle its train in two parts if stalled for any reason in the sag, may be used to reduce the construction cost without decreasing the train rating or the efficiency of the railway, and should be used where economy in construction cost is thereby effected, except at points where train stops or reduced speed, below the limit necessary to operate the gradient, are likely to be necessary.

(b) MAXIMUM AND MINIMUM SPEED.—In the calculation of the lengths of momentum gradients the maximum speed of freight trains at the bottom of the sag should not exceed the speed limit for such trains on the engine district under consideration; and the minimum speed at the top of the gradient, where the velocity gradient adjoins an ascending gradient of any considerable length, should not be less than 11 miles per hour. Where the top of the momentum gradient is at a summit, the minimum speed may be less than 11 miles per hour.

(c) VERTICAL CURVES.—In fixing the grade line for any alinement, care should be taken to insert vertical curves at all grade line intersections.

(10) Passing Sidings and Water Stations

(a) PREFERABLE LOCATIONS.—Passing sidings and road water supplies should preferably be located on minor summits.

(b) GRADE COMPENSATION.—If passing sidings must of necessity be located on ruling gradients, then such gradients should, if practicable, be compensated for the whole length of the siding and for a full train length beyond each end, so as to permit the maximum train load which can be hauled over the ruling gradient to be started from a full stop at any point within the limits given. Due consideration must also be given to the compensation required on the curves at each end of the turnout.

(C) COMPARISON OF DIFFERENT LINES

(11) Scope of Comparisons

(a) A line may be a reconnaissance, a preliminary, a projection, a location, or a railroad (constructed line).

(b) Comparisons may be made between any two or more lines of the same or different kind.

(12) Method of Comparison

To determine the relative value of distance, curvature, rise and fall, it is necessary to decide upon the methods of studying the effects of these factors on the cost of maintenance and operation.

The location of terminal points, ruling gradient and pusher gradients having been decided upon, the effect of distance, curvature, rise and fall upon operating expenses may be determined in the following manner:

(a) DISTANCE.—Distance is the length of line.

Distance affects train wages, line resistance, maintenance of way and maintenance of equipment.

The effect of distance on line resistance will be found in the fuel account.

The effect of distance on train wages can be computed on a direct train mile basis, except where arbitrary mileage allowances for a day's run are made.

The effect of distance on maintenance of way is a more complicated problem on account of the uncertainty as to the basis on which maintenance should be calculated. A fixed sum per mile to cover factors of maintenance that are more or less constant plus a rate for the equivalent ton-mile unit, using multiples for weights of engines and passenger cars, is correct in principle, but until such time as information is obtained as to the value of these multiples, this item may be calculated on the basis of a constant per mile plus a fixed sum per train mile.

The effect of distance on maintenance of equipment, for comparative purposes, may be calculated on a train mile basis.

(b) DISTANCE AND REVENUE.—In comparing lines of varying lengths, consideration must be given to the effect of distance on revenue. Another item worthy of consideration is the fact that reducing distance in engine runs of less than 100 miles, which constitute the entire day's work for trainmen employed on same, may not reduce the amount of wages to be paid to such employees.

(c) CURVATURE.—A straight line is the ideal alinement.

Curvature is the number of degrees of central angle subtended by the line; it may be divided into sharp curvature, necessitating a reduction in speed, and flat curvature, which can be divided into curvature increasing line resistance in both directions and curvature increasing line resistance in one direction only.

Curvature increases the resistance by about 0.8 lb. per ton per degree of central angle, which is equivalent to a rise of 0.04 ft. per degree of central angle; it also affects the cost of maintenance of way and the cost of maintenance of equipment, but sufficient data are not available to warrant a conclusion as to the definite amounts.

The justifiable expenditure to eliminate one degree of central angle in the alinement of roadway depends largely on the number of daily trains and the cost per train per mile.

As a general rule it is good practice to spend more money to take out one degree of central angle where the radius is small, requiring the maximum elevation of the outer rail, than where the radius is large, requiring less elevation.

As a general rule, it is justifiable to spend more money to take out one degree of central angle where trains run at a higher rate of speed than where the speed is low.

Curves should be connected to tangents by spiral or easement curves of such length as to provide ample space in which to make the required elevation, giving due consideration to future requirements of increased speeds.

(d) CURVE RESISTANCE—FREIGHT CARS.—Tests made on the Canadian Pacific Railway at Winnipeg on wheels of freight cars running on curved and straight tracks demonstrate that:

(1′) All outer wheels of railway cars exert a pressure against the outer rail when rounding a curve.

(2′) The cause of this pressure is the tendency of a cylindrical body to rotate in a straight line at angles to the axis of rotation.

(3′) There is never any skidding of either wheel of the leading axle of a truck unless it is a forward skidding of both wheels caused by the resistance to rotation being great enough to cause a slightly retardation to rotation which results in an apparent forward skidding.

(4′) There is no skidding of the outer wheel of a rear axle, and in general any skidding that does take place is on the inner wheel of the rear axle.

These tests also suggest that as the flange is pressed against the rail, the concave curve at the base of the flange increases the effective diameter of the outer wheel so as to prevent skidding of the wheels of the front axle and to minimize, if not entirely prevent, skidding of either wheel of the rear axle.

(Tests did not include engine driving wheels.)

(e) LINE RESISTANCE.—Line resistance is the sum of the rolling resistance (frictional resistance) plus the resistance of gravity overcoming difference in elevation in ascending grades, plus the resistance due to curvature, minus the energy of gravity on trains on descending grades, from which has been subtracted the loss of energy (velocity head) due to application of brakes.

In comparing different locations the resistance under average conditions should be used.

(1′) FRICTIONAL RESISTANCE.—The frictional resistance of freight trains under normal conditions in warm weather with modern equipment running at speeds between 7 and 35 miles per hour may be determined with sufficient accuracy for the purpose of comparing different gradients and locations by the formula:

$$R = 2.2\,T + 121.6\,C;$$

where R = Total resistance on level tangent;
T = Total weight of cars and contents in tons;
C = Total number of cars in train.

The values thus obtained will usually be from 3 to 8 lb. per ton and a fair average for mixed traffic may be taken at 6 lb. per ton. For convenience in the comparison of two or more locations the total resistance may be converted into feet of rise. Thus, 1 lb. per ton resistance is practically equivalent to 2½ ft. of rise per mile.

Train resistance increases at lower temperatures and at extremely low temperature may be so great as 30 lb. per ton for empty freight cars. Normal conditions should be assumed for the comparison of different locations in the same country.

(2′) CURVE RESISTANCE.—The resistance due to curvature may be assumed to be equivalent to 0.04 ft. of rise for each degree of central angle.

(3′) RISE AND FALL.—Rise and fall affect line resistance and may affect time, but to what measurable extent is indeterminate.

The amount of rise and fall of each alternate location in vertical feet should generally be determined and considered as an aid to judgment in forming final decision as between locations, but may be neglected entirely in comparing alternate locations where there is small difference in rise and fall.

(4′) TRAIN RESISTANCE

- (a′) Dynamometer tests to be of the greatest value should show the following:
  - (1″) Dynamometer record (graphical) showing drawbar pull to nearest ten pounds, with horizontal scale not less than 400 feet to one inch and in special cases a larger scale.
  - (2″) Speed record to nearest tenth of mile per hour (graphical).
  - (3″) Key to record mile posts.
  - (4″) Condition of track surface and gage (graphical).
  - (5″) Steam pressure of boiler (graphical).
  - (6″) Train line air pressure (graphical).
  - (7″) Time record (graphical). (Speed record may be independent record and in this case time record is desirable.)
  - (8″) Coal consumption (record of shovels of coal used) (worked by hand in engine).
- (b′) REQUISITE DATA TO BE TAKEN:

Track

- (9″) Office profile and alinement connecting with mile posts (so as to connect with (d′)).
- (10″) Section of rail.
- (11″) Condition of rail.
- (12″) Number of ties to rail (and rail length).
- (13″) Kind and quantity of ballast.

Locomotive

(14″) Type (wheel arrangement, whether simple or compound and dimensions of locomotive).
(15″) Total weight and weight on drivers.

Cars

(16″) Record of length, initial, number, class of each car of train; also weight empty and weight loaded.
(17″) Kind of truck.
(18″) Condition of car.

Weather

(19″) Temperature.
(20″) Direction of force of wind and direction of train.
(21″) State of weather (rainy or clear).

(c′) VALUE APPROXIMATE ONLY

Numerous tests demonstrate that there is no absolute value for train resistance. For practical purposes freight train resistance can be considered constant between velocities of 7 and 35 miles per hour.

(d′) FORMULAS

The following formulas are practicable where train has been in motion at least fifteen minutes.

Assuming that:

A Rating is used at temperatures of 35 degrees Fahr. or higher,

B Rating is used at temperatures between 20 and 35 degrees Fahr.,

C Rating is used at temperatures between 0 and 20 degrees Fahr., and

D Rating is used at temperatures below 0 degrees Fahr.

A Rating: $R = 2.2\,T + 122\,C$ (on level grade)
B Rating: $R = 2.2\,T + 122\,C$ (on level grade)
C Rating: $R = 4.0\,T + 153\,C$ (on level grade)
D Rating: $R = 5.4\,T + 171\,C$ (on level grade)

when $R =$ total resistance of train in pounds.
$T =$ tonnage of train in tons of 2000 pounds.
$C =$ the number of cars in the train.

Percentages of adjusted rating *"B," "C"* and *"D"* are shown in the following table:

"A" RATING TAKEN AS 100%

Per Cent. Grade	Adjustment	"B"	"C"	"D"
0.1	29	84	70	57
0.15	23	87	74	62
0.2	20	89	78	66
0.25	17	90	80	69
0.3	15	91	82	72
0.35	13	92	84	74
0.4	12	93	85	76
0.45	11	93	86	78
0.5	10	94	87	79
0.55	9	94	88	81
0.6	9	95	89	82
0.65	9	95	89	83
0.7	8	95	90	84
0.75	7	96	91	84
0.8	7	96	91	85
0.85	6	96	91	86
0.9	6	96	92	86
1.0	5	97	93	87
1.1	5	97	93	88
1.2	5	97	93	89
1.3	4	97	94	90
1.4	4	97	94	91
1.5	4	98	95	91
1.6	4	98	95	92
1.7	3	98	95	92
1.8	3	98	96	93
1.9	3	98	96	93
2.0	3	98	96	93
2.1	3	98	96	93
2.2	3	98	96	94
2.3	2	98	96	94
2.4	2	98	96	94
2.5	2	99	97	94
2.6	2	99	97	94
2.7	2	99	97	95
2.8	2	99	97	95
2.9	2	99	97	95
3.0	2	99	97	95

(e′) Curve Compensation

(1″) Compensate .03 per degree:

When the length of curve is less than half the length of the longest train.

When a curve occurs within the first 20 feet of rise of a grade.

When curvature is in no sense limiting.

("2) Compensate .035 per degree:

When curves are between one-half and three-quarters as long as the longest train.

When curve occurs between 20 feet and 40 feet of rise from the bottom of the grade.

(3″) Compensate .04 per degree:

Where the curve is habitually operated at low speed.

Where the length of the curve is longer than three-quarters of the length of the longest train.

Where elevation is excessive for freight trains.

At all places where curvature is likely to be limiting.

(4″) Compensate .05 per degree wherever the loss of elevation can be spared.

(f′) Condition of roadway maintenance has a great effect on train resistance.

(g′) Condition and design of equipment has a great effect on train resistance.

(h′) Resistance of individual cars of same weight but of different type shows considerable variation. Sufficient data are not yet available to determine just how much the difference is.

(i′) Starting resistance varies from 10 to 40 lb. per ton, depending on loading, temperature and character of maintenance of roadway and equipment.

(f) TIME.—As saving of time is an economic operation, this item should be taken into consideration and given proper value as the condition may warrant.

(g) METHODS OF ESTIMATING SPEED, TIME AND FUEL CONSUMPTION

(1′) SPEED AND FUEL CONSUMPTION.—Speed should be differentiated as between speed based on running time between stops and speed based on elapsed time between terminals.

Elapsed time is the sum of delays plus running time. Time lost in delays varies with congestion and generally constitutes an important though not a major part of total elapsed time.

Delays may be divided into terminal and road delays and are due to many things such as coaling, getting water, picking up, setting off and switching, helper service, couplers, hot boxes and blocking by trains ahead. The last may be by far the most important single item, constituting in certain cases approximately one-half of total delays.

In view of the multiplicity of varying conditions which contribute to delays, no definite rule of estimating them can be given except the very general rule of basing the estimate on a study of past performance under similar physical, operating and traffic conditions.

(2′) SPEED CURVE METHOD.—Speed and running time between stops may be estimated as follows:

By means of acceleration and retardation curves computed for the given engine, fuel, train load and gradients, compute and preferably plat the speed curve on the profile. Platting, though not strictly necessary, as computations can be made without it, has many advantages.

A profile showing the grade line, coal and water stations, other stations, number of tracks, passing tracks, curvature, etc., to a scale of 2000 ft. to the inch horizontally, and 20 ft. vertically, or other convenient scale, may be used.

Estimate the time by multiplying the distance in stations by the time (n) in decimals of a minute required to travel one station at the given speed. This can be measured by a scale showing values of (n) for corresponding speeds. Where the speed varies appreciably, the time should be taken for separate intervals of distance, 10 stations, 5 stations, or less, as in such case the distance multiplied by the value of (n) for the average speed does not give the correct time.

Multiply the total time of engine working and drifting by the corresponding rates of fuel consumption. To this may be added fuel consumption for engine firing up and standing.

(3′) Speed Curve Method Modified.—By using the same general methods, diagrams may be constructed showing for a given engine and train, or for a tonnage constituting any number of such trains, speed, time lost and fuel consumed per foot of rise and fall on various grades as compared with the performance of the same engine and train on a level tangent. The latter is readily computed. This method is especially adapted to computations as to the negative value of rise and the positive value of fall and should accomplish practically the same result as platting the speed line on the profile, except that stops are omitted and must be considered separately, if at all.

(4′) Line Resistance as a Measure of Fuel Consumption.—Fuel consumption may be estimated on the basis of line resistance as described elsewhere in the Manual. The method may be expanded to include resistance due to accelerating trains by adding the velocity head destroyed by brakes at stops to total line resistance in vertical feet.

This method has the advantage of great simplicity and may be useful in many problems. It is based on a uniform rate of fuel consumption per foot-ton of line resistance. But as a steam locomotive burns considerably more coal per horsepower at low than at high speeds it should be understood that this method will not indicate the full disadvantage of heavy adverse grades where low speeds prevail.

The average fuel per foot-ton of line resistance will vary with the thermal value of the coal, and for any operating division may be approximated by dividing the total line resistance into the fuel consumed, making deductions for the amount consumed by the engine firing up, standing and accelerating from stops.

(h) Special Structures.—The maintenance and operation of special structures must be considered on their respective merits for each location.

(13) Inertia Resistance

The above method must be understood to disregard the resistance due to accelerating trains. This may or may not be a considerable part of the total resistance, depending upon rates of grade and the distances between stops.

Inertia resistance, or the added energy required to increase the velocity of a train from V_1 velocity to V_2 velocity may be computed by the formula:

$$P = (V_2^2 - V_1^2)\,\frac{70}{s},$$

where P = required force in pounds per ton;
V_2 and V_1 = the higher and lower velocities respectively in miles per hour;
s = distance in feet in which such acceleration is accomplished.

For many calculations V_1 = zero.

The formula allows 5 per cent for the extra energy required to produce rotation of the wheels and axles.

(II) POWER

(A) General Principles Applicable to All Classes

(1) Drawbar Pull.—Actual drawbar pull of the locomotive at various speeds should be used in making estimates with reference to economic value of various locations of line and gradient, where such drawbar pull is known. Where not known, the drawbar pull should be calculated. In comparing a new line with an existing line the same percentage of efficiency of drawbar pull should be used in both cases.

(2) Conversion of Horsepower to Tractive Force.—Horsepower can be converted into tractive force by the formula, tractive force equals 375 times the H.P., divided by the velocity in miles per hour. To simplify the operation the tractive force can be obtained by multiplying the H.P. by the figures shown in Table 2.

(B) Steam

(3) Tractive Force.—The tractive force of a locomotive depends upon its steam producing capacity, the boiler pressure, the adhesion, and the size of the cylinders and drivers.

(a) Steam Producing Capacity

(1′) The steam producing capacity of a locomotive depends mainly upon the quantity and quality of the fuel burned, and the area of heating surfaces.

(2′) Knowing the area of the heating surface, the average steam production of locomotives burning bituminous and similar coals can be estimated by the use of Table 4, assuming the maximum quantity of coal that can be properly fired and consumed per hour, to be as follows:

Hand-fired locomotives, 4,000 lb. per hour.

Stoker-fired locomotives with grates less than 70 square feet, 6,000 lb. per hour.

Stoker-fired locomotives with grates of 70 square feet or over, 8,000 lb. per hour.

These amounts are to be understood as the average hourly fuel consumption which may reasonably be expected to be maintained throughout the periods when the locomotive is working steam.

(3′) The maximum velocity at which full cutoff can be maintained can be found by dividing the pounds steam produced per minute by the quantity of steam used per revolution of drivers as shown in Table 5. Dividing this quotient by the coefficient given in Table 3 for the diameter of the drivers will give the speed in miles per hour at which full cutoff can be maintained. This velocity is referred to as "M" in the tables.

(b) VARIATIONS IN TRACTIVE FORCE

(4′) Tractive force of a locomotive is greatest at starting, gradually reducing to the maximum velocity ("M") at which full cutoff can be maintained. At speeds above this velocity the tractive force decreases more rapidly. The tractive force at any multiple of "M" is practically a fixed percentage of the tractive force at "M." The fixed percentages are different for compound types than for simple locomotives.

Where I.H.P. at "M" velocity has been converted into cylinder tractive force, the cylinder tractive force at other multiples of "M" can be determined by using the percentages given in Table 6 without first calculating the I.H.P. for the respective multiples of "M."

(4) LOCOMOTIVE HORSEPOWER.—Knowing the steam production of a locomotive and the maximum velocity at which full cutoff can be maintained ("M"), the indicated horsepower of a locomotive can be obtained for velocity "M" or higher velocities by dividing the total steam produced per hour by the quantity of steam used per I.H.P. hour, as given in Table 6, after applying the corrections for proper boiler pressure in the case of a locomotive using saturated steam.

(5) DRAWBAR PULL.—Available drawbar pull on level tangent is the cylinder tractive force less the sum of the resistance from the cylinder to the rim of drivers, the resistance through the trucks of engine and tender, and the "head end" or velocity resistance. The formulas and data given in Table 1 are recommended for use in determining these resistances. Available drawbar pull at starting, with use of sand, should not be considered as greater than 30 per cent of the weight on locomotive drivers and at running speeds not greater than 25 per cent.

TABLE 1

LOCOMOTIVE RESISTANCES.

Ⓐ Cylinder to Rim of Drivers:
Total Pounds $R=18.7T+80N$.
T=Tons Weight on Drivers.
N=Number Driving Axles.

Ⓑ Engine and Tender Trucks:
Total Pounds $R=2.6T+20N$.
T=Tons Weight on Engine and Tender Trucks.
N=Number of Truck Axles.

Ⓒ Head End or "Air" Resistance.
$R=.002V^2A$;......
V=Velocity in Miles per Hour.
A=Area (Average for Locomotives, 125 sq. ft.).

Total $R=0.25V^2$

Air Resistance (C) for Various Velocities.

Velocity	R	Velocity	R	Velocity	R	Velocity	R
1	0.25	11	30	21	110	31	240
2	1.00	12	36	22	121	32	256
3	2.25	13	42	23	132	33	272
4	4.00	14	49	24	144	34	289
5	6.25	15	56	25	156	35	306
6	9.00	16	64	26	169	36	324
7	12.25	17	72	27	182	37	342
8	16.00	18	81	28	196	38	361
9	20.25	19	90	29	210	39	380
10	25.00	20	100	30	225	40	400

Drawbar pull on level tangent equals the cylinder Tractive Power less the sum of Engine Resistances.

At Low Speeds the adhesion of drivers should be considered and available drawbar pull should never be estimated greater than 30 per cent. of Weight on Drivers at starting with use of sand, 25 per cent. of Weight on Drivers at running speeds.

TABLE 2

POUNDS TRACTIVE POWER FOR ONE HORSEPOWER AT VARIOUS SPEEDS.

$$\text{Formula: One H. P.} = \frac{375}{\text{Velocity in miles per hour}}$$

Velocity	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3	125.0	120.97	117.19	113.64	110.29	107.14	104.17	101.35	98.68	96.15
4	93.75	91.46	89.29	87.21	85.23	83.33	81.52	79.79	78.13	76.53
5	75.00	73.53	72.12	70.75	69.44	68.18	66.96	65.79	64.66	63.56
6	62.50	61.48	60.48	59.52	58.59	57.69	56.82	55.97	55.15	54.35
7	53.57	52.82	52.08	51 37	50.68	50.00	49.34	48.70	48.08	47.47
8	46.88	46.30	45.74	45 18	44.64	44.12	43.60	43.10	42.61	42.13
9	41.67	41.21	40.76	40 32	39.89	39 47	39.06	38.66	38.27	37.88
10	37.50	37.13	36.77	36.41	36.06	35.71	35.38	35.05	34.72	34.40
11	34.09	33.78	33.48	33.19	32.89	32.61	32.33	32.05	31.78	31.51
12	31.25	30.99	30.74	30.49	30.24	30.00	29.76	29.53	29.30	29.07
13	28.85	28.63	28.41	28.20	27.99	27.78	27.57	27.37	27.17	26.98
14	26.79	26.60	26.41	26.22	26.04	25.86	25.68	25.51	25.34	25.17
15	25.00	24.83	24.67	24 51	24.35	24.19	24.04	23.88	23.73	23.58
16	23.44	23.29	23.15	23.01	22.87	22.73	22.59	22.46	22.32	22.19
17	22.06	21.93	21.80	21.68	21.55	21.43	21.31	21.19	21.07	20.95
18	20.83	20.72	20.60	20.49	20.38	20.27	20.16	20.05	19.95	19.84
19	19.74	19.63	19.53	19.43	19.33	19.23	19.13	19.03	18.94	18.84
20	18.75	18.66	18.56	18 47	18.38	18.29	18.20	18.12	18.03	17.94
21	17.86	17.77	17.69	17.61	17.52	17.44	17.36	17.28	17.20	17.12
22	17.05	16.97	16.89	16.82	16.74	16.67	16.59	16.52	16.45	16.37
23	16.30	16.23	16.16	16.09	16.03	15.96	15.89	15.82	15.76	15.69
24	15.63	15.56	15.50	15.43	15.37	15.31	15.24	15.18	15.12	15.06
25	15.00	14.94	14.88	14.82	14.76	14.71	14.65	14.59	14.53	14.48
26	14.42	14.37	14.31	14.26	14.20	14.15	14.10	14.04	13.99	13.94
27	13.89	13.84	13.79	13.74	13.68	13.63	13.59	13.54	13.49	13.44
28	13.39	13.35	13.30	13.25	13.20	13.16	13.11	13.07	13.02	12.98
29	12.93	12.89	12.84	12.80	12.76	12.71	12.67	12.63	12.58	12.54
30	12.50	12.46	12.42	12.38	12.34	12.30	12.26	12.22	12.18	12.14
31	12.10	12.06	12.02	11.98	11.94	11.90	11.87	11.83	11.79	11.76
32	11.72	11.68	11.65	11.61	11.57	11.54	11.50	11.47	11.43	11.40
33	11.36	11.33	11.30	11.26	11.23	11.19	11.16	11.13	11.09	11.06
34	11.03	11.00	10.96	10.93	10.90	10.87	10.84	10.81	10.78	10.74
35	10.71	10.68	10.65	10.62	10.59	10.56	10.53	10.50	10.47	10.44
36	10.42	10.39	10.36	10.33	10.30	10.27	10.24	10.21	10.18	10.16

For intermediate velocities, values per horsepower can be found by interpolation.

TABLE 3

VALUES OF COEFFICIENT "C" FOR CHANGING REVOLUTIONS PER MINUTE OF DRIVERS INTO VELOCITY IN MILES PER HOUR

$$``C" = \frac{336.13}{\text{Diameter of drivers in inches.}}$$

$$\text{Miles per hour} \doteq \frac{\text{Revolutions per minute}}{``C"}$$

Diam.	"C"	Diam.	"C"	Diam.	"C"	Diam.	"C"
50 in.	6.72	58 in.	5.79	66 in.	5.09	74 in.	4.54
51 "	6.59	59 "	5.69	67 "	5.01	75 "	4.48
52 "	6.46	60 "	5.60	68 "	4.94	76 "	4.42
53 "	6.34	61 "	5.51	69 "	4.87	77 "	4.36
54 "	6.22	62 "	5.42	70 "	4.80	78 "	4.31
55 "	6.11	63 "	5.33	71 "	4.73	79 "	4.25
56 "	6.00	64 "	5.25	72 "	4.67	80 "	4.20
57 "	5.89	65 "	5.17	73 "	4.60	81 "	4.15

TABLE 4

AVERAGE EVAPORATION IN LOCOMOTIVE BOILERS

Burning bituminous and similar coals of various qualities and for various quantities consumed per square foot of heating surface per hour.

Based on Feed Water at 60° Fahrenheit. Boiler Pressure, 200 lbs.

Lbs. Coal per Sq. Ft. H. Surface per Hour	POUNDS STEAM PER POUND OF COAL OF GIVEN THERMAL VALUE					
	10,000 B. T. U.	11,000 B. T. U.	12,000 B. T. U.	13,000 B. T. U.	14,000 B. T. U.	15,000 B. T. U.
0.8	5.24	5.76	6.29	6.81	7.34	7.86
0.9	5.05	5.56	6.06	6.57	7.07	7.58
1.0	4.87	5.36	5.85	6.34	6.82	7.31
1.1	4.71	5.18	5.65	6.12	6.59	7.06
1.2	4.55	5.00	5.46	5.91	6.37	6.82
1.3	4.39	4.83	5.27	5.71	6.15	6.59
1.4	4.25	4.67	5.10	5.52	5.95	6.37
1.5	4.11	4.52	4.94	5.35	5.76	6.17
1.6	3.98	4.38	4.78	5.18	5.57	5.97
1.7	3.86	4.25	4.63	5.02	5.40	5.79
1.8	3.74	4.12	4.49	4.86	5.24	5.61
1.9	3.63	3.99	4.35	4.71	5.08	5.44
2.0	3.51	3.86	4.22	4.57	4.92	5.27
2.1	3.41	3.75	4.10	4.44	4.78	5.12
2.2	3.31	3.64	3.98	4.31	4.64	4.97
2.3	3.22	3.54	3.86	4.19	4.51	4.83
2.4	3.13	3.44	3.75	4.07	4.38	4.69
2.5	3.04	3.34	3.65	3.95	4.26	4.56
2.6	2.96	3.25	3.55	3.84	4.14	4.44
2.7	2.88	3.17	3.46	3.74	4.03	4.32
2.8	2.80	3.09	3.37	3.64	3.93	4.21
2.9	2.73	3.01	3.28	3.55	3.83	4.10
3.0	2.66	2.93	3.19	3.46	3.73	3.99

The quantity of steam evaporated for intermediate quantities or qualities of coal can be found by interpolation.

On bad water districts deduct the following from tabular quantities:

For each $\frac{1}{16}$-inch of accumulated scale .... 10 per cent.

For each grain per U. S. gallon of foaming salts in the average feed water .... 1 per cent.

For locomotive using superheated steam, the heating surface mentioned in column 1 is to be understood as total water-heating surface only—superheating surface is not included.

TABLE 5

WEIGHT OF STEAM USED IN ONE FOOT OF STROKE IN LOCOMOTIVE CYLINDERS.

(a) For locomotives using saturated steam.

Cylinder diameter is for high pressure cylinders in compound locomotives.

Diameter of Cylinder in Inches	WEIGHT OF STEAM PER FOOT STROKE FOR VARIOUS GAGE PRESSURES						
	160 lb.	170 lb.	180 lb.	190 lb.	200 lb.	210 lb.	220 lb.
12	0.304 lb.	0.321 lb.	0.337 lb.	0.354 lb.	0.370 lb.	0.389 lb.	0.405 lb.
13	0.357 "	0.376 "	0.396 "	0.415 "	0.435 "	0.456 "	0.475 "
14	0.414 "	0.436 "	0.459 "	0.482 "	0.504 "	0.529 "	0.551 "
15	0.476 "	0.501 "	0.527 "	0.553 "	0.579 "	0.607 "	0.633 "
15½	0.508 "	0.535 "	0.562 "	0.590 "	0.618 "	0.649 "	0.675 "
16	0.541 "	0.570 "	0.599 "	0.629 "	0.658 "	0.691 "	0.720 "
17	0.611 "	0.643 "	0.676 "	0.710 "	0.744 "	0.780 "	0.812 "
18	0.685 "	0.722 "	0.759 "	0.796 "	0.834 "	0.875 "	0.911 "
18½	0.724 "	0.762 "	0.801 "	0.841 "	0.881 "	0.924 "	0.962 "
19	0.763 "	0.804 "	0.845 "	0.887 "	0.928 "	0.975 "	1.015 "
19½	0.804 "	0.847 "	0.890 "	0.934 "	0.978 "	1.027 "	1.069 "
20	0.846 "	0.891 "	0.936 "	0.983 "	1.029 "	1.080 "	1.125 "
20½	0.888 "	0.936 "	0.984 "	1.032 "	1.081 "	1.134 "	1.181 "
21	0.932 "	0.982 "	1.032 "	1.083 "	1.134 "	1.191 "	1.240 "
22	1.023 "	1.078 "	1.133 "	1.189 "	1.245 "	1.307 "	1.361 "
23	1.118 "	1.178 "	1.238 "	1.300 "	1.361 "	1.428 "	1.487 "
28	1.657 "	1.745 "	1.835 "	1.926 "	2.017 "	2.117 "	2.204 "

For weight of steam used per revolution of drivers at full cutoff:—Multiply the tabular quantity by four times the length of stroke in feet for simple and four cylinder compounds. For two cylinder compounds multiply by two times the length of stroke.

(b) For simple locomotives using superheated steam.

Diameter of Cylinder in Inches	WEIGHT OF STEAM PER FOOT OF STROKE FOR VARIOUS GAGE PRESSURES					
	160 lb.	170 lb.	180 lb.	190 lb.	200 lb.	210 lb.
18	.415	.443	.470	.498	.524	.551
19	.465	.496	.526	.557	.587	.618
20	.515	.549	.582	.617	.650	.684
21	.565	.605	.641	.679	.715	.752
22	.623	.665	.705	.747	.787	.827
23	.682	.728	.772	.818	.861	.905
24	.741	.791	.838	.889	.931	.984
25	.804	.859	.910	.965	1.016	1.065
26	.868	.927	.983	1.041	1.097	1.150
27	.937	1.000	1.057	1.123	1.163	1.241
28	1.008	1.078	1.143	1.209	1.275	1.340
29	1.083	1.156	1.225	1.299	1.368	1.438
30	1.157	1.234	1.308	1.387	1.460	1.533

This assumes a superheat of 200 degrees Fahrenheit, and a drop of 5 lb. per square inch in pressure between the boilers and the cylinders.

TABLE 6.

PER CENT. CYLINDER TRACTIVE POWER
FOR
VARIOUS MULTIPLES OF "*M*."

"*M*"=Maximum Velocity in Miles per hour at which Boiler Pressure can be maintained with full cutoff.

(a) For locomotives using saturated steam.

Velocity	Compound per cent.	Simple per cent.	Velocity	Compound per cent.	Simple per cent.	Velocity	Compound per cent.	Simple per cent.
Start	(Simple) 135.00	106.00	3.6 M	32.40	44.75	6.4 M		23.59
0.5 M	103.00	103.00	3.7 "	31.25	43.56	6.5 "		23.18
1.0 "	100.00	100.00	3.8 "	30.10	42.39	6.6 "		22.79
1.1 "	96.28	95.57	3.9 "	29.14	41.24	6.7 "		22.42
1.2 "	92.55	91.53	4.0 "	28.24	40.10	6.8 "		22.06
1.3 "	88.83	87.83	4.1 "	27.38	39.00	6.9 "		21.71
1.4 "	85.12	84.46	4.2 "	26.56	37.96	7.0 "		21.38
1.5 "	81.40	81.37	4.3 "	25.77	36.97	7.1 "		21.06
1.6 "	77.68	78.55	4.4 "	25.03	36.03	7.2 "		20.75
1.7 "	73.96	75.97	4.5 "	24.34	35.13	7.3 "		20.45
1.8 "	70.25	73.60	4.6 "	23.69	34.26	7.4 "		20.16
1.9 "	66.54	71.41	4.7 "	23.07	33.41	7.5 "		19.88
2.0 "	63.21	69.37	4.8 "	22.48	32.59	7.6 "		19.61
2.1 "	60.20	67.47	4.9 "	21.92	31.82	7.7 "		19.34
2.2 "	57.48	65.67	5.0 "	21.38	31.11	7.8 "		19.08
2.3 "	54.97	63.94	5.1 "	20.87	30.42	7.9 "		18.82
2.4 "	52.68	62.22	5.2 "	20.37	29.75	8.0 "		18.57
2.5 "	50.42	60.55	5.3 "	19.89	29.10	8.1 "		18.33
2.6 "	48.16	58.92	5.4 "	19.43	28.48	8.2 "		18.09
2.7 "	46.08	57.33	5.5 "	18.99	27.87	8.3 "		17.86
2.8 "	44.10	55.78	5.6 "		27.33	8.4 "		17.64
2.9 "	42.29	54.26	5.7 "		26.81	8.5 "		17.43
3.0 "	40.57	52.78	5.8 "		26.30	8.6 "		17.22
3.1 "	38.95	51.33	5.9 "		25.81	8.7 "		17.01
3.2 "	37.42	49.91	6.0 "		25.34	8.8 "		16.82
3.3 "	35.98	48.55	6.1 "		24.88	8.9 "		16.63
3.4 "	34.66	47.24	6.2 "		24.44	9.0 "		16.45
3.5 "	33.53	45.97	6.3 "		24.01			

(b) For simple locomotives using superheated steam

Velocity	Per Cent	Velocity	Per Cent	Velocity	Per Cent	Velocity	Per Cent
Start	106.00	2.7 M	47.12	4.5 M	31.19	6.3 M	22.90
0.5 M	103.00	2.8 M	45.82	4.6 M	30.61	6.4 M	22.56
1.0 M	100.00	2.9 M	44.61	4.7 M	30.05	6.5 M	22.21
1.1 M	92.42	3.0 M	43.49	4.8 M	29.52	6.6 M	21.89
1.2 M	86.55	3.1 M	42.30	4.9 M	29.00	6.7 M	21.57
1.3 M	81.20	3.2 M	41.21	5.0 M	28.48	6.8 M	21.24
1.4 M	76.95	3.3 M	40.17	5.1 M	27.96	6.9 M	20.92
1.5 M	73.00	3.4 M	39.22	5.2 M	27.47	7.0 M	20.62
1.6 M	69.55	3.5 M	38.30	5.3 M	27.00	7.1 M	20.32
1.7 M	66.60	3.6 M	37.42	5.4 M	26.53	7.2 M	20.07
1.8 M	63.66	3.7 M	36.61	5.5 M	26.10	7.3 M	19.78
1.9 M	61.27	3.8 M	35.89	5.6 N	25.69	7.4 M	19.52
2.0 M	58.96	3.9 M	35.11	5.7 M	25:26	7.5 M	19.26
2.1 M	56.94	4.0 M	34.39	5.8 M	24.86	7.6 M	19.01
2.2 M	55.12	4.1 M	33.72	5.9 M	24.46	7.7 M	18.76
2.3 M	53.26	4.2 M	33.06	6.0 M	24.04	7.8 M	18.52
2.4 M	51.53	4.3 M	32.40	6.1 M	23.66	7.9 M	18.28
2.5 M	49.98	4.4 M	31.79	6.2 M	23.28	8.0 M	18.06
2.6 M	48.50						

TABLE 7

Pounds of Steam per I. H P. Hour For Various Multiples of "*M*."

(a) For locomotives using saturated steam.

"*M*"=Maximum velocity in miles per hour at full cutoff.
Boiler pressure, 200 lbs.

Velocity	Pounds Steam per I. H. P. Hour		Velocity	Pounds Steam per I. H. P. Hour	
	Simple Locomotive	Compound Locomotive		Simple Locomotive	Compound Locomotive
1.0 M	38.30	25.80	2.9 M.	24.37	21.04
1.1 "	36.46	24.36	3.0 "	24.22	21.21
1.2 "	34.89	23.24	3.2 "	24.00	21.57
1.3 "	33.56	22.35	3.4 "	23.85	21.93
1.4 "	32.41	21.65	3.6 "	23.80	22.27
1.5 "	31.40	21.14	3.8 "	23.80	22.57
1.6 "	30.49	20.77	4.0 "	23.87	22.85
1.7 "	29 67	20.52	4.25 "	24.05	23.22
1.8 "	28.93	20.40	4.50 "	24.24	23.56
1.9 "	28.25	20.40	4.75 "	24.44	23.85
2.0 "	27.62	20.40	5.00 "	24.64	24.15
2.1 "	27.05	20.40	5.5 "	24.98	24.70
2.2 "	26.52	20.40	6.0 "	25.20	
2.3 "	26.06	20.40	6.5 "	25.45	
2.4 "	25.67	20.40	7.0 "	25.60	
2.5 "	25.32	20.47	7.5 "	25.70	
2.6 "	25.02	20.60	8.0 "	25.80	
2.7 "	24.76	20.73	9.0 "	25.90	
2.8 "	24.54	20.88			

For steam per I. H. P. hour for other boiler pressures take the following percentages of values given in table:

160 lb., 103 per cent.	190 lb., 100.6 per cent.
170 lb., 102.1 per cent.	210 lb., 99.5 per cent.
180 lb., 101.3 per cent.	220 lb., 99.2 per cent.

(b) For simple locomotives using superheated steam.

Velocity	Pounds of Steam Per I. H. P. Hour.	Velocity	Pounds of Steam Per I. H. P. Hour.
1.0 M	24.00	2.8 M	18.70
1.1 "	23.58	2.9 M	18.55
1.2 "	23.10	3.0 M	18.40
1.3 "	22.74	3.2 M	18.20
1.4 "	22.28	3.4 M	18.00
1.5 "	21.92	3.6 M	17.79
1.6 "	21.55	3.8 M	17.60
1.7 "	21.20	4.0 M	17.44
1.8 "	20.90	4.25 M	17.26
1.9 "	20.59	4.5 M	17.10
2.0 "	20.32	4.75 M	16.96
2.1 "	20.05	5.0 M	16.86
2.2 "	19.81	5.5 M	16.72
2.3 "	19.60	6.0 M	16.63
2.4 "	19.40	6.5 M	16.62
2.5 "	19.22	7.0 M	16.62
2.6 "	19.02	8.0 M	16.62
2.7 "	18.86		

COMMITTEE XVII

WOOD PRESERVATION

[1]WOOD PRESERVATION

GENERAL PROVISIONS

(1) Creosote and zinc chloride are effective wood preservatives when properly applied and when used under proper conditions.

(2) Bridge material and any wood which is to be treated should have all framing and boring done as far as possible before treating.

(3) It is better to inject quantities of chemicals in excess of the requirements than to skimp the treatment in any way.

(4) Chemicals used should be tested for purity from time to time.

(5) When treating with creosote or creosote coal-tar solution the quantity to be used should be specified in gallons for ties, posts, cross-arms and other material of uniform size, and in pounds per cubic foot for other material.

(6) Absorption of creosote should be based on the treatment which will give the most complete penetration for each class or kind of wood, specifying complete penetration of the sapwood and as much of the heartwood as possible.

(7) In order to determine the penetration of the oil, borings should be made with an increment borer in at least six pieces in each cylinder load. The holes should be plugged with creosoted plugs at least one-sixteenth inch larger than the diameter of the hole.

(8) Ties treated with water soluble salts should be allowed to dry some time before they are put in the track.

(9) Daily reports should be kept at the works and duplicates sent to the General Office, if desired, in order to check the operation.

(10) Accurate records should be kept in order to form proper conclusions as to the merits of different methods and processes.

(11) Preserved wood may be destroyed by mechanical action long before it is decayed, and, therefore, should be protected by economical devices when the mechanical life limits the life of the tie.

(12) For best results it is recommended that certain sections of track be selected on each railroad for the purpose of making accurate tests covering the life of treated and untreated ties of various kinds of timber and various treatments, and that a record be kept of all ties in these sections of track in order to be able thereafter to improve treatment. All ties inserted in such test sections should be marked with dating nails, and, if necessary, with other identification marks.

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[1] Adopted, Vol. 10, 1909, pp. 629-631, 669-676; Vol. 11, Part 2, 1910, pp. 737, 761, 859; Vol. 15, 1914, pp. 632, 1088; Vol. 18, 1917, pp. 1271, 1579; Vol. 20, 1919, pp. 126, 840; Vol. 27, 1926, pp. 921, 1414.

PREPARATION AND HANDLING OF WOOD BEFORE AND AFTER TREATMENT[2]

GROUPING

(1) It is essential that wood should be grouped properly in order that successful treatment may be obtained. The species, the proportion of heartwood and sapwood, the condition of the timber with respect to its moisture content and wood structure will determine, in general, this grouping.

(2) Pieces of wood of approximately the same size and of approximately the same period of seasoning should be grouped together; green and seasoned pieces should not be mixed.

(3) Pine and other coniferous woods should be separated on the basis of the percentage of heartwood and sapwood.

(4) Grouping of the pieces by species and families is desirable. From this it follows that red oak, beech, longleaf pine, loblolly pine, and gum should be stacked and treated separately. Birch, beech, and hard maples are examples of the grouping of species which may be stacked and treated together.

STACKING

(5) Ties should be stacked in layers of one or two and seven to ten.

(6) Caps, stringers, and other large timbers should be stacked so as to leave air spaces between adjacent pieces in the same layer and the layers should be separated by 4 in. by 4 in. strips.

(7) Piling should be stacked according to length, using strips 4 in. by 4 in., or saplings of equal size, between each layer.

(8) Lumber should be segregated according to size and each layer in a stack separated by strips at least one inch thick, and an air space of one inch or more left between each piece of lumber in every layer.

(9) All wood should be piled on treated sills or other non-decaying material in such manner that in the case of ties there will be a space of at least 6 inches between the bottom of the lowest tier and the ground, and in the case of timbers or piling, a space of at least 12 inches.

The space in the seasoning yard under and between the rows of stacks should be kept free at all times from rotting wood, weeds, and rubbish. The yard should be drained so that no water can stand under the stacks or in their immediate vicinity.

The seasoning yard should be so arranged that adjacent stacks of ties, timber, piling, etc., have an alley-way at least 3 feet wide between them.

SEASONING

(10) Wood should not be treated until seasoned. Air seasoning is preferable, as most woods can be treated best after being air seasoned. If the material arrives at the plant in a sufficiently seasoned condition, it may be loaded directly to the trams for treatment but if otherwise, it should be stacked in the yard for air seasoning.

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[2] Adopted, Vol. 13, 1912, pp. 864, 1040-1041; Vol. 21, 1920, pp. 325-334, 1385; Vol. 23, 1922, pp. 979, 1169; Vol. 27, 1926, pp. 914, 1414; Vol. 28, 1927, pp. 1114, 1427.

Since the rate of seasoning varies with the latitude, time of year, the exposure, and the climatic peculiarities of the season, it is essential to establish the seasoning period for each class of wood and for any particular locality.

(11) Wood piled for seasoning should be closely watched and not allowed to over-season or deteriorate. No wood should be treated which does not conform to the requirements of the specifications as to shakes, checks, etc.

(12) Wood which shows signs of checking should be provided with "S" irons, bolts, or other devices to prevent further checking, both before and after treatment.

ADZING, BORING AND FRAMING

(13) All adzing, boring, and framing should be done before treatment.

CARE OF WOOD AFTER TREATMENT

(14) It is recommended that timber be allowed to season for at least 60 days after treatment. It should be piled with spacer strips to give complete air circulation.

In addition to other advantages, the fire hazard is greatly reduced when treated material is allowed to season about 60 days after treatment. It has been demonstrated that seasoned creosoted material is more resistant to fire than either untreated or freshly creosoted material.

(15) In handling treated material, extreme care should be used to avoid damage to the edges of the timbers or breaking through the portions penetrated by the treatment and exposing untreated wood.

The use of peavies, canthooks, timber dogs, pickaroons, lug hooks, or other pointed tools on treated lumber should be absolutely prohibited.

Creosoted timber piled for seasoning or storage should be sheltered as much as possible from the direct rays of the sun. Cross sticks should be placed sufficiently close to prevent long timbers or those of small section from sagging and becoming crooked, and every care should be taken to prevent the checking which exposes untreated wood.

The top layer of stacked timbers should be covered with sand or dirt to the depth of not less than one-half inch as protection from the sun, and all grass or rubbish should be cleaned from under and around the stacked material to lessen the danger from fire.

(16) It is recommended that creosoted piles should not be used with untreated piles in any structure except under special conditions.

The use of dogs may be employed in rafting piles provided these are placed within one foot of the head or 4 feet of the point.

Peavies or loading tongs should not be used except within one foot of the head or 4 feet of the tip. Rope slings should be used for unloading and handling. Tongs may be used, when confined to the ends as outlined above, for lifting so that slings may be placed.

A sharp pointed tool should not be used to turn a pile in the gins of the driver. This can be done with a spud and sling.

Piles should not be bored for staging. For piling driven in water or with the cut-off high above the ground, staging clamps may be used. These may be made of two flat bars, bent to semi-circles and bolted together around the pile. A tail turns up at one end of the iron and projects sufficiently to carry the supporting timber on which the staging plank is laid.

When a clamp has been placed loosely around a pile, it is slipped up to the desired position and broad wooden wedges driven from the under side and the clamp tightens as the weight comes on it. The wooden wedges also compensate for variation in the diameter of the piling. Only a few sizes of clamps are necessary.

All treated pile cut-offs and chamfered tops where the piles project beyond the caps should be saturated with hot creosote by repeated applications, and then daubed with hot asphaltum or a mixture of creosote and roofing pitch mixed to a vaseline-like consistency, and swabbed in with a long handled brush. For chamfered tops, it is recommended that a suitable fabric be embedded in the hot asphaltum, or roofing pitch and creosote, and that the outside of this fabric be given an additional coating of the waterproofing material.

Piles should not be adzed to accommodate sway braces. The braces should be fitted to a surface by filling between the brace and the pile with treated timber blocks and using longer bolts where necessary.

Holes bored for drift pins should be 1/16 inch smaller than the drift. This is not recommended for sway brace bolts, as the thread of the bolt has a tendency to sliver the pile on the opposite side. Where possible holes bored in creosoted material should be filled with hot creosote, followed by a mixture of creosote and roofing pitch.

After the bolt is driven a portion of the pitch creosote mixture should be placed under the washers at both ends of the bolt which, when the bolt is tightened, gives a water-tight job under the washers. Pitch can usually be worked in between the timbers before tightening to give further protection. With proper care, decay from sway brace bolt holes can be practically eliminated.

Any holes that may be made either in top or side surfaces and which are not used should be plugged with treated material. The plug should be dipped in creosote and driven to the bottom of the hole. Holes, abrasions, or checks too large to be plugged should be treated with hot creosote and filled with the mixture of creosote and roofing pitch. This may then be protected by sheet copper held in place with copper nails or by special roofing material, laid with the weather side out and coated with the pitch mastic on the outside.

Bridge crews handling creosoted piling and other creosoted material should keep on hand a supply of creosote, bridge cement, or roofing pitch, saturated fabric, and creosoted shimming and plugging material.

(17) Sway braces should be fitted from the bottom and any cutting to length found necessary should be at the top. The cut should then be treated with hot creosote, creosote and bridge cement or roofing pitch and fabric as necessary to protect it from the weather.

(18) Creosoted lumber, and particularly long or heavy timbers which have been framed prior to treatment, should be stacked with special care to avoid warping or distortion while the material is in storage.

(19) Care should be exercised in unloading and distributing creosoted cross-ties in order to avoid splintering the edges and exposing untreated wood. Any holes bored after treatment and any holes resulting from drawn spikes should be plugged with creosoted plugs.

Ties should be adjusted to position with tie tongs or a pry and not hammered. If ties are driven at all, this should be done with a 'wooden maul.

When the adzing of creosoted ties is unavoidable, as may happen in connection with change of rail, care should be taken to cover the adzed area with at least two applications of hot creosote. The same treatment should be given to all exposed untreated wood.

[3]SPECIFICATIONS FOR THE PRESERVATIVE TREATMENT OF WOOD

A complete treating specification should contain the following:

Material.—Material shall conform to the Association's standard specification for the particular class desired.

Treating Process.—The process used shall conform to one of the Association's specifications for treating processes.

Preservative.—The preservative used shall conform to one of the following standards of the Association.

Creosote, Grades 1, 2, or 3,
Creosote Coal-Tar Solution,
Zinc Chloride.

Amount of Preservative.—For the amount of creosote to be used per cubic foot see the following table. For the amount of zinc chloride to be used see the specifications for zinc chloride treatment.

QUANTITIES OF CREOSOTE FOR VARIOUS CLASSES OF WOOD.—The quantities of creosote given in this table apply to all classes of treatable wood except Douglas fir and western larch. The quantities of creosote in terms of pounds per cubic foot final retention given in the following table may be considered a safe guide in the treatment of various items of wood used in maintenance of way construction. Where special conditions obtain it may be necessary to increase or decrease these quantities to fit special cases—for instance, where the table specifies 16 lb. for land piling with sapwood more than 2 inches, it may be necessary to increase this to 18 or 20 lb. or more for piles having 4 inches of sapwood or more.

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[3] Adopted, Vol. 28, 1927, pp. 1117, 1427.

TABLE 1

Class of Material	Process and Pounds Creosote Per Cubic Foot		
	Full Cell	Lowry	Rueping
Ballast Deck Bridge Plank	16	..	..
Bridge Caps	16	..	..
Bridge Stringers	16	..	..
Bridge Ties	..	10	10
Bulkhead Plank	16	..	..
Building Lumber	..	8	8
Car Lumber	..	8	8
Conduit	..	8	8
Cross and Switch Ties	..	8	8
Crossing Plank	..	8	8
Cross Arms	..	6	6
Dock Stringers, Caps, and Timbers	16	..	..
Drain Box and Culvert Lumber	14	14	14
Farm Gates	..	6	6
Fence Posts and Boards	..	6	6
Guard Rails	..	10	10
Ice House Lumber	14	14	14
Longitudinal Braces	16	..	..
Piling—Marine	22 or refusal		
Piling, Land, Sapwood less than 2 in.	12	..	..
Piling, Land, Sapwood more than 2 in.	16	..	..
Platform Plank	..	8	8
Poles	..	10	10
Sills for Frame Buildings	14	14	14
Sign Posts	12	12	12
Stock Pen Posts and Lumber	12	12	12
Sway Braces	16	..	..
Tie Plugs	12	12	12
Trunking and Capping (Wires in Petroleum Asphalt)	12	12	12
Trunking and Capping (Wires Loose in Trunking)	..	8	8
Water Tank Staves	12	..	..

[4]SPECIFICATIONS FOR TREATING PROCESSES

CREOSOTE (FULL CELL PROCESS)

(1) Except when ordered otherwise by the railroad's representative, the material shall be air-seasoned until in his judgment any moisture in it will not prevent injection of the specified amount of preservative; shall be restricted in any charge to woods into which approximately equal quantities of preserving fluid can be injected; and shall consist of pieces approximately equal in size and sapwood content, on which all framing, boring or adzing shall have been done, so separated as to insure contact of steam and preservatives with all surfaces.

(2) The preservative used shall be the one most suitable and available of the following standards of the American Railway Engineering Association:

Creosote Grades 1, 2, or 3,
Creosote Coal-tar solution.

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[4] Adopted, Vol. 21, 1920, pp. 325-334, 1385; Vol. 27, 1926, pp. 914, 1414; Vol. 28, 1927, pp. 1114, 1427.

(3) The material shall retain the amount of creosote necessary to permeate all of the sapwood and as much of the heartwood as practicable. The quantity of creosote retained shall be calculated, on the basis of 100 deg. Fahr., from readings of working tank gages and scales, or from weights of at least one-tenth of the material on a suitable track scale before and after treatment, checked as may be desired by the railroad's representative.

(4) After the material is placed in the cylinder, a vacuum of at least 22 inches shall be maintained until the wood is as dry and as free of air as practicable. The creosote shall then be introduced, without breaking the vacuum, until the cylinder is filled. The pressure shall be gradually raised, and maintained at a minimum of 125 lb. per square inch until the required quantity of preservative is injected into the material, or failing this, until the railroad's representative is satisfied that the largest volumetric injection that is practicable has been obtained. The temperature of the preservative during the pressure period shall be not less than 170 deg. Fahr., nor more than 200 deg. Fahr., and shall average at least 180 deg. Fahr. After pressure is completed and the cylinder emptied of preservative, a vacuum shall be maintained until the material can be removed from the cylinder free of dripping preservative.

(5) At least once each day the railroad's representative shall determine penetration by sampling ties at middle and rail sections; from other material samples shall be taken as desired. Any holes that may be bored shall be filled with tight-fitting creosoted plugs.

(6) The treating plant shall be equipped with the thermometers and gages necessary to indicate and record accurately the conditions at all stages during the treatment, and all equipment shall be maintained in condition satisfactory to the railroad. The owner of the treating plant shall also provide and keep in condition for use at all times the apparatus and chemicals necessary for making the analyses and tests required in this specification.

(7) When permission is given to prepare material for treatment by steaming instead of seasoning by air, it shall not be subjected to pressures or temperatures sufficient to injure the wood.

CREOSOTE—LOWRY PROCESS (EMPTY CELL PROCESS WITH FINAL VACUUM)

(1) Except when ordered otherwise by the railroad's representative, the material to be treated shall be air-seasoned until in his judgment any moisture in it will not prevent injection of an adequate amount of preservative; shall be confined in any charge to woods into which approximately equal quantities of preserving fluid can be injected; and shall consist of pieces approximately equal in size and sapwood content, on which all framing, boring or adzing shall have been done, so separated as to insure contact of steam and preservative with all surfaces.

(2) The preservative used shall be the one most suitable and available of the following standards of the American Railway Engineering Association:

Creosote Grades, 1, 2, or 3,
Creosote Coal-tar Solution.

(3) The material shall retain the quantity of creosote shown in Table 1, page 1278, which will permeate all of the sapwood and as much of the heartwood as practicable, and no charge shall contain less than 90 per cent nor more than 110 per cent of the quantity per cubic foot that may be specified; but the average retention of preservative by the material treated under any contract or order shall be at least 100 per cent of the quantity specified. The quantity of preservative retained shall be calculated, on the basis of 100 deg. Fahr., from readings of working tank gages or scales or from weights of a least one-tenth of the material on a suitable track scale before and after treatment, checked as may be desired by the railroad's representative.

(4) After the material is placed in the cylinder, the preservative shall be introduced, at not over 200 degrees Fahr., until the cylinder is filled.

(5) The pressure shall be raised and maintained until there is obtained the largest practicable volumetric injection that can be reduced to the required retention by a quick high vacuum. The pressure and temperature within the cylinder shall be so controlled as to give the maximum penetration by the quantity of preservative injected. After the pressure is completed the cylinder shall be speedily emptied of preservative and a vacuum of at least 22 inches promptly created and maintained until the quantity of preservative injected is reduced to the required retention.

(6) At least once each day the railroad's representative shall determine penetration by sampling ties at middle and rail sections; from other material samples shall be taken as desired. Any holes that may be bored shall be filled with tight-fitting creosoted plugs.

(7) The treating plant shall be equipped with the thermometers and gages necessary accurately to indicate and record conditions at all stages during the treatment, and all equipment shall be maintained in condition satisfactory to the railroad. The owner of the treating plant shall also provide and keep in condition for use at all times the apparatus and chemicals necessary for making the analyses and tests required in this specification.

CREOSOTE—RUEPING PROCESS (EMPTY CELL PROCESS WITH INITIAL AIR AND FINAL VACUUM)

(1) Except when ordered otherwise by the railroad's representative, the material to be treated shall be air-seasoned until in his judgment any moisture in it will not prevent injection of an adequate amount of preservative; shall be restricted in any charge to woods into which approximately equal quantities of preserving fluid can be injected; and shall consist of pieces approximately equal in size and sapwood content, on which all framing, boring, or adzing shall have been done, so separated as to insure contact of air and preservative with all surfaces.

(2) The preservative used shall be the one most suitable and available of the following standards of the American Railway Engineering Association:

Creosote Grades, 1, 2, or 3,
Creosote Coal-tar Solution.

(3) The material shall retain the quantity of creosote shown in Table 1, page 1278, which shall permeate all of the sapwood and as much of the heartwood as practicable, and no charge shall retain less than 90 per cent nor more than 110 per cent of the quantity per cubic foot that may be specified; but the average retention of preservative by the material treated under any contract or order shall be at least 100 per cent of the quantity specified. The amount of preservative retained shall be calculated, on the basis of 100 degrees Fahr., from readings of working tank gages or scales or from weights of at least one-tenth of the material on a suitable track scale before and after treatment, checked as may be desired by the railroad's representative.

(4) After the material is placed in the cylinder it shall be subjected to air pressure of sufficient intensity and duration to provide under a vacuum the ejection of preservative necessary to insure the required retention. For example: With red oak pressures of 4 to 60 lb. for 30 minutes, while with pine having a large percentage of sapwood pressures of 70 to 90 lb. for 30 minutes will be required. The preservative shall then be introduced, the air pressure being maintained constant until the cylinder is filled. The pressure shall be gradually raised to at least 150 lb. per square inch, and maintained until all of the sapwood and as much of the heartwood as practicable is saturated, or failing this, until the railroad's representative is satisfied that the largest volumetric injection that is practicable has been obtained. The temperature of the preservative during the pressure period shall be not less than 170 degrees Fahr., nor more than 200 degrees Fahr., and shall average at least 180 degrees Fahr. After the pressure is completed the cylinder shall be speedily emptied of preservative and a vacuum of at least 22 inches be promptly created, and maintained until the material can be removed from the cylinder free of dripping preservative.

(5) At least once each day the railroad's representative shall determine penetration by sampling ties at middle and rail sections; from other material samples shall be taken as desired. Any holes that may be bored shall be filled with tight-fitting creosoted plugs.

(6) The treating plant shall be equipped with the thermometers and gages necessary to indicate and record accurately the conditions at all stages during the treatment, and all equipment shall be maintained in condition satisfactory to the railroad. The owner of the treating plant shall also provide and keep in condition for use at all times the apparatus and chemicals necessary for making the analyses and tests required in this specification.

ZINC CHLORIDE

(1) Except when ordered otherwise by the railroad's representative, the material to be treated shall be air-seasoned until in his judgment any moisture in it will not prevent injection of the specified amount of preservative; shall be restricted in any charge to woods into which approximately equal quantities of preserving fluid can be injected; and shall consist of pieces approximately equal in size and sapwood content, on which all framing, boring, or adzing shall have been done, so separated as to insure contact of steam and preservative with all surfaces.

(2) The zinc chloride used shall be in accordance with the A.R.E.A. Specifications.

(3) The material shall retain an average of 0.5 lb. of dry zinc chloride per cubic foot, which shall permeate all of the sapwood and as much of the heartwood as practicable, and no charge shall retain less than 90 per cent nor more than 110 per cent of this quantity; but the average retention of preservative by the material treated under any contract or order shall be at least 100 per cent of the quantity specified.

(4) The treating solution shall be no stronger than necessary to obtain the required retention of preservative with the largest volumetric absorption that is practicable, and shall be thoroughly mixed before use. Its strength shall not exceed 5 per cent and shall be determined by analysis. Chemical titration, using a silver-nitrate solution with potassium-chromate indicator, will usually be satisfactory. For example: With red oak the strength shall not exceed 4 per cent, and the volume injected shall be not less than 20 per cent, while with pine having a large percentage of sapwood it shall not exceed 2 per cent, and the volume injected shall be not less than 40 per cent. The amount of solution retained shall be calculated from readings of working tank gages or scales or from weights of at least one-tenth of the material on a suitable track scale before and after treatment, checked as may be desired by the railroad's representative.

(5) Air-seasoned material shall be steamed in the cylinder for not less than one hour nor more than two hours, at a pressure of not more than 20 lb. per square inch, the cylinder being provided with vents to relieve it of stagnant air and insure proper circulation of the steam and being drained to prevent condensate from accumulating in sufficient quantity to reach the material. After steaming is completed, a vacuum of at least 22 inches shall be maintained until the wood is as dry and as free from air as practicable. Before the preservative is introduced, the cylinder shall be drained of condensate, and if the vacuum is broken, a second one as high as the first shall be created. The preservative shall be introduced, without breaking the vacuum until the cylinder is filled. The pressure shall be gradually raised and maintained at a minimum of 125 pounds per square inch until the required quantity of preservative is injected into the material, or until less than 5 per cent of the total quantity required has been injected during the latter half of one hour throughout which the rate of injection has persistently decreased while the pressure has been held continuously at 165 or more lb. per square inch. The temperature of the preservative during the pressure period shall be not less than 130 degrees Fahr., nor more than 190 degrees Fahr., and shall average at least 150 degrees Fahr. After the cylinder is emptied of preserving solution, a vacuum shall be maintained until the material can be removed from the cylinder free of dripping preservative.

(6) At least once each day the railroad's representative shall determine penetration by analysis. The "Iodine-Potassium Ferricyanide Starch" color reaction test to determine the penetration by its visibility will generally be satisfactory.

(7) From ties, samples shall be taken at middle and rail sections; from other material samples shall be taken as desired. Any holes that may be bored shall be filled with tight-fitting treated plugs.

(8) The treating plant shall be equipped with the thermometers and gages necessary to indicate and record accurately the conditions at all stages during the treatment, and all equipment shall be maintained in condition satisfactory to the railroad. The owner of the treating plant shall also provide and keep in condition for use at all times apparatus and chemicals necessary for making the analyses and tests required in this specification.

ZINC CHLORIDE AND CREOSOTE—CARD PROCESS

(1) Except when ordered otherwise by the railroad's representative, the material to be treated shall be air-seasoned until in his judgment any moisture in it will not prevent injection of the specified amount of preservative; shall be restricted in any charge to woods into which approximately equal quantities of preserving fluid can be injected; and shall consist of pieces approximately equal in size and sapwood content, on which all framing, boring, or adzing shall have been done, so separated as to insure contact of steam and preservative with all surfaces.

(2) The zinc chloride shall conform to the standard A.R.E.A. Specifications.

(3) The creosote shall meet the standard for Grade 3 Creosote.

(4) The material shall retain an average of 0.5 lb. of dry zinc chloride and 3 lb. of creosote per cubic foot, which shall permeate all of the sapwood and as much of the heartwood as practicable, and no charge shall retain less than 90 per cent nor more than 110 per cent of these quantities per cubic foot; but the average retention of preservative by the material treated under any contract or order shall be at least 100 per cent of the quantity specified.

(5) The preserving mixture shall be composed of the volumetric proportion of creosote and of zinc chloride solution of the necessary strength which are required to obtain the specified retention of the preservatives with the largest volumetric injection that is practicable, and shall be agitated in the working tank and cylinder so as to insure thorough mixing before and while the cylinder is being filled with preservative and while the preservative is being injected into the material. The strength of the zinc chloride solution shall not exceed 5 per cent and shall be determined by analysis. Chemical titration—using a silver nitrate solution with potassium-chromate indicator, before the zinc chloride solution is mixed with the creosote oil, will usually be satisfactory. For example: With red oak the proportion shall be not less than 77 per cent of 5 per cent zinc chloride solution and not more than 23 per cent of creosote oil, and the volume injected shall be not less than 20 per cent, while with pine having a large percentage of sapwood they shall be not less than 88 per cent of 2.5 per cent zinc chloride and not more than 12 per cent of creosote and the volume injected shall not be less than 40 per cent. The quantities of preservatives retained shall be calculated from readings of work-

ing tank gages or scales and from weights of at least one-tenth of the material on a suitable track scale before and after treatment, checked as may be desired by the railroad's representative.

(6) Air-seasoned material shall be steamed in the cylinder for not less than one hour nor more than two hours, at a pressure of not more than 20 lb. per square inch, the cylinder being provided with vents to relieve it of stagnant air and insure proper circulation of the steam and being drained to prevent condensate from accumulating in sufficient quantity to reach the material. After steaming is completed, a vacuum of at least 22 inches shall be maintained until the wood is as dry and as free from air as practicable. Before the preservative is introduced the cylinder shall be drained of condensate, and if the vacuum is broken a second one as high as the first shall be created. The preserving mixtures shall be introduced without breaking the vacuum until the cylinder is filled. The pressure shall be gradually raised, and maintained at a minimum of 125 lb. per square inch until the required amount of preservative is injected into the material, or until less than 5 per cent of the total quantity required has been injected during the latter half of one hour throughout which the rate of injection has persistently decreased while the pressure has been held continuously at 165 or more pounds per square inch. The temperature of the preservative during the pressure period shall be not less than 170 degrees Fahr., nor more than 200 degrees Fahr., and shall average at least 180 degrees Fahr. After the cylinder is emptied of preserving mixture, a vacuum shall be maintained until the material can be removed from the cylinder free of dripping preservative.

(7) At least once each day the railroad's representative shall determine penetration by analysis. The "Iodine - Potassium Ferricyanide Starch" color reaction test to determine the penetration by its visibility will generally be satisfactory. From ties, samples shall be taken at middle and rail sections; from other material samples shall be taken as desired. Any holes that may be bored shall be filled with tight-fitting creosoted plugs.

(8) The treating plant shall be equipped with the thermometers and gages necessary to indicate and record accurately the conditions at all stages during the treatment, and all equipment shall be maintained in condition satisfactory to the railroad. The owner of the treating plant shall also provide and keep in condition for use at all times the apparatus and chemicals necessary for making the analyses and tests required in this specification.

(9) When water-gas-tar solution instead of creosote is used, it shall meet the following requirements:

(10) The oil shall be a water gas-tar product, of which at least sixty per cent shall be a distillate of water gas-tar and the remainder shall be refined or filtered water gas-tar. It shall comply with the following requirements:

1. It shall not contain more than 3 per cent water.
2. It shall not contain more than 2 per cent of matter insoluble in benzol.
3. The specific gravity of the oil at 38/15.5 degrees Centigrade shall not be less than 1.03 nor more than 1.07.

4. The distillate, based on water-free oil, shall be within the following limits:
    Up to 210 degrees Centigrade, not more than 8 per cent.
    Up to 235 degrees Centigrade, not more than 20 per cent.
    Up to 355 degrees Centigrade, not less than 60 per cent.
5. The specific gravity of the fractions between 235 degrees Centigrade and 315 degrees Centigrade shall not be less than .98 nor more than 1.02 at 38/15.5 degrees Centigrade.
6. The residue above 355 degrees Centigrade, if it exceeds 5 per cent, shall have a float test of not more than 50 seconds at 70 degrees Centigrade.
7. The oil shall not yield more than 10 per cent coke residue.
8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

When a distillate of water gas tar is used, it shall meet the following requirements:

The oil shall be a distillate of water gas tar. It shall comply with the following requirements:

1. It shall not contain more than 3 per cent of water.
2. It shall not contain more than 0.5 per cent of matter insoluble in benzol.
3. The specific gravity of the oil at 38/15.5 degrees Centigrade shall be not less than 1.02.
4. The distillate, based on water-free oil, shall be within the following limits:
    Up to 210 degrees Centigrade, not more than 5 per cent.
    Up to 235 degrees Centigrade, not more than 25 per cent.
    Up to 355 degrees Centigrade, not less than 80 per cent.
5. The specific gravity of the fractions between 235 degrees Centigrade and 315 degrees Centigrade shall not be less than .98 nor more than 1.02 at 38/15.5 degrees Centigrade.
6. The residue above 355 degrees Centigrade, if it exceeds 5 per cent shall have a float test of not more than 50 seconds at 70 degrees Centigrade.
7. The oil shall not yield more than 2 per cent coke residue.
8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

ZINC-TANNIN

(1) The zinc chloride solution shall be introduced and adequate pressure shall be applied and maintained until the desired absorption is obtained. The amount of solution injected shall be equivalent to ½-lb. of dry soluble zinc chloride per cubic foot of timber. The solution shall be as weak as can be used and still obtain the desired absorption of zinc chloride, and shall not be stronger than 5 per cent.

(2) The solution shall be heated to a temperature of not less than 140 degrees Fahr. before admission to the cylinder. If the cylinders are provided with steam coils, steam shall be maintained in these coils during the entire treatment.

(3) The cylinder shall be entirely filled with preservative, and so maintained while the pressure is on, an air vent being provided by which the air in the cylinder and that coming from the charge while under pressure may be released.

4. After the required amount of zinc chloride has been injected, this solution shall be run off and the ties allowed to drain for 15 minutes. The chloride draining off shall be blown or run off, and a 2 per cent solution of tannic acid, made by mixing 6⅔ lb. of 30 per cent extract of tannin with 100 lb. of water, run in, and a pressure of 100 lb. produced and maintained one-half hour. This shall then be run off, a 1 per cent solution of glue (made by dissolving 2 1/10 lb. of glue containing 50 per cent gelatine in 100 lb. water) shall be admitted to the cylinder, and a pressure of 100 lb. produced and maintained for one-half hour. Care shall be taken to maintain the solutions containing the glue and tannic acid up to their original strength in these elements.

(5) The zinc chloride used shall be in accordance with A.R.E.A. Standard Specifications. The amount of chloride specified to be injected shall be of soluble zinc chloride only. The amount of solution absorbed shall be determined by calculation based on the gage readings of the tank holding the supply of solution. This should be checked occasionally by weighing the ties loaded on the cylinder tram cars, before and after treatment, a scale being inserted in the tram tracks. The strength of the zinc chloride solution shall be carefully controlled from time to time by hydrometer readings. Borings shall be taken from time to time from at least six ties treated in the same run, and a determination of the actual zinc chloride according to the standard method made. The holes made in taking these borings shall be plugged tightly and completely with creosoted plugs.

[5]SPECIFICATIONS FOR PRESERVATIVES

CREOSOTE, GRADE ONE

The oil shall be a distillate of coal-gas or coke-oven tar. It shall comply with the following requirements:

1. It shall contain not more than 3 per cent of water.
2. It shall contain not more than 0.5 per cent of matter insoluble in benzol.
3. The specific gravity of the oil at 38/15.5 degrees Centigrade shall be not less than 1.03.
4. The distillate, based on water-free oil, shall be within the following limits:

   Up to 210 degrees Centigrade not more than 5 per cent.
   Up to 235 degrees Centigrade not more than 25 per cent.

5. The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall be not less than 1.03 at 38/15.5 degrees Centigrade.

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[5] Adopted, Vol. 20, 1919, pp. 122, 124, 838, 839; Vol. 21, 1920, pp. 325, 1384; Vol. 27, 1926, pp. 935, 1414.

The specific gravity of the fraction between 315 degrees Centigrade and 355 degrees Centigrade shall be not less than 1.10 at 38/15.5 degrees Centigrade.

6. The residue above 355 degrees Centigrade, if it exceeds 5 per cent, shall have a float test of not more than 50 seconds at 70 degrees Centigrade.

7. The oil shall yield not more than 2 per cent coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

In addition to the oil conforming to the above standard specification, the two grades specified below may be used when the higher grade oil cannot be procured:

CREOSOTE, GRADE TWO

The oil shall be a distillate of coal-gas or coke-oven tar. It shall comply with the following requirements:

1. It shall contain not more than 3 per cent of water.

2. It shall contain not more than 0.5 per cent of matter insoluble in benzol.

3. The specific gravity of the oil at 38/15.5 degrees Centigrade shall be not less than 1.03.

4. The distillate, based on water-free oil, shall be within the following limits:

Up to 210 degrees Centigrade not more than 8 per cent.
Up to 235 degrees Centigrade not more than 35 per cent.

5. The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall be not less than 1.03 at 38/15.5 degrees Centigrade.

The specific gravity of the fraction between 315 degrees Centigrade and 355 degrees Centigrade shall be not less than 1.10 at 38/15.5 degrees Centigrade.

6. The residue above 355 degrees Centigrade, if it exceeds 5 per cent, shall have a float test of not more than 50 seconds at 70 degrees Centigrade.

7. The oil shall yield not more than 2 per cent coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

CREOSOTE, GRADE THREE

The oil shall be a distillate of coal-gas or coke-oven tar. It shall comply with the following requirements:

1. It shall contain not more than 3 per cent of water.

2. It shall contain not more than 0.5 per cent of matter insoluble in benzol.

3. The specific gravity of the oil at 38/15.5 degrees Centigrade shall be not less than 1.03.

4. The distillate, based on water-free oil, shall be within the following limits:

Up to 210 degrees Centigrade not more than 10 per cent.
Up to 235 degrees Centigrade not more than 40 per cent.

5. The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall be not less than 1.03 at 38/15.5 degrees Centigrade.

The specific gravity of the fraction between 315 degrees Centigrade and 355 degrees Centigrade shall be not less than 1.10 at 38/15.5 degrees Centigrade.

6. The residue above 355 degrees Centigrade, if it exceeds 5 per cent, shall have a float test of not more than 50 seconds at 70 degrees Centigrade.

7. The oil shall yield not more than 2 per cent coke residue.

8. The foregoing tests shall be made in accordance with the standard methods of the American Railway Engineering Association.

It is urged that when Grades 2 or 3 are used, consideration be given to the injection of a greater quantity of creosote per cubic foot.

CREOSOTE COAL-TAR SOLUTION

The oil shall be a coal-tar product, of which at least 80 per cent shall be a distillate of coal-gas or coke-oven tar, and the remainder shall be refined or filtered coal-gas or coke-oven tar. It shall comply with the following requirements:

1. It shall contain not more than 3 per cent of water.

2. It shall contain not more than 2 per cent of matter insoluble in benzol.

3. The specific gravity of the oil at 38/15.5 degrees Centigrade shall be not less than 1.05 nor more than 1.12.

4. The distillate, based on water-free oil, shall be within the following limits:

Up to 210 degrees Centigrade not more than 5 per cent.
Up to 235 degrees Centigrade not more than 25 per cent.

5. The specific gravity of the fraction between 235 degrees Centigrade and 315 degrees Centigrade shall be not less than 1.03 at 38/15.5 degrees Centigrade.

The specific gravity of the fraction between 315 degrees Centigrade and 355 degrees Centigrade shall be not less than 1.10 at 38/15.5 degrees Centigrade.

6. The residue above 355 degrees Centigrade, if it exceeds 26 per cent, shall have a float test of not more than 50 seconds at 70 degrees Centigrade.

7. The oil shall yield not more than 6 per cent coke residue.

8. The foregoing tests shall be made in accordance with the recommended methods of the American Railway Engineering Association.

ZINC CHLORIDE

Zinc chloride shall be acid-free and shall not contain more than 0.1 per cent iron. Dry zinc chloride shall contain at least 94 per cent soluble zinc chloride, and in any solution specified the percentage of zinc chloride specified shall be the amount of soluble zinc chloride required.

MEASURING, SAMPLING AND ANALYZING PRESERVATIVES

[6]STANDARD TEMPERATURE FOR MEASURING CREOSOTE

All volumetric measurements of creosote shall be referred to the volume at 100 degrees Fahr. as standard.

In making corrections for volume, the correction is 1 per cent for every 22½ degrees Fahr., equivalent to .00044 per degree Fahr.

[7]WATER IN CREOSOTE

Allowable Limits of Water

The use of creosote in treatment containing up to 3 per cent water is permissible. Where the quantity exceeds 3 per cent proper allowance should be made, but under no circumstances shall timbers be treated with oils having more than 6 per cent water.

Measurement

In all cases where water separates in the tank or car, the water should be taken off to as great an extent as practicable and the measurement then should be made from the point of separation between the remaining water and creosote as nearly as this can be determined. This refers to the physical process of measurement.

Sampling for Water Content

It is recommended as good practice that, in order to obtain accurate determinations as to the percentage of water contained in creosote in tank cars and in storage tanks, the principle of zone sampling be employed, and that for the purpose of obtaining zone samples an apparatus of the type illustrated (Fig. 1) be used.

Storage Tanks

All storage tanks should have a watertight roof.

STANDARD METHOD OF SAMPLING CREOSOTE IN TANK CARS

Apparatus

The sampling device shall be a brass cylinder having a capacity of about one quart with a pointed perforated bottom. The openings are closed by means of a spring valve, which is operated by means of a wire extended along and held in place by the extended stem attached to the cylinder. The stem is made in several sections. It is calibrated in feet and inches from the openings in the cylinder to the top of the stem. The straight walled part of the cylinder is 12 inches long and 2½ inches in diameter. (See Fig. 1.)

One-quart friction top cans to receive contents of samples, one for each 1-foot zone in the car to be sampled.

A thermometer with range about 0 degree Fahr. to 200 degrees Fahr., preferably having a metal case and cup which will withdraw a small amount of oil surrounding the bulb.

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[6] Adopted, Vol. 10, Part 1, pp. 621, 1909; Vol. 27, 1926, pp. 938, 1414.

[7] Adopted, Vol. 15, 1914, pp. 632, 1088; Vol. 27, 1926, pp. 938, 1414.

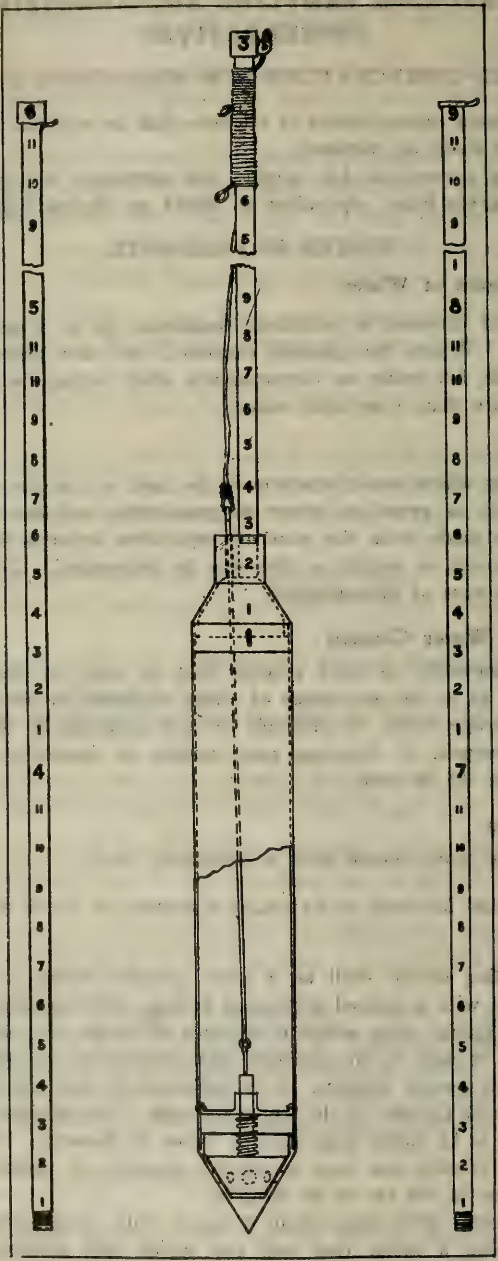

Fig. 1—Details of Zone Sampling Apparatus

Procedure

Samples shall be taken as follows:

1. Determine by inserting a thin wooden pole that the contents of the car are reasonably liquid throughout its depth.

2. Determine the temperature of the oil in the tank car.

3. Determine the inside diameter of the shell in feet and inches from the point marked "A" in Fig. 1-Z.

4. Refer to Table 1, whose tabulations provide for any tank car from 6 feet 0 inches to 8 feet 0 inches diameter.

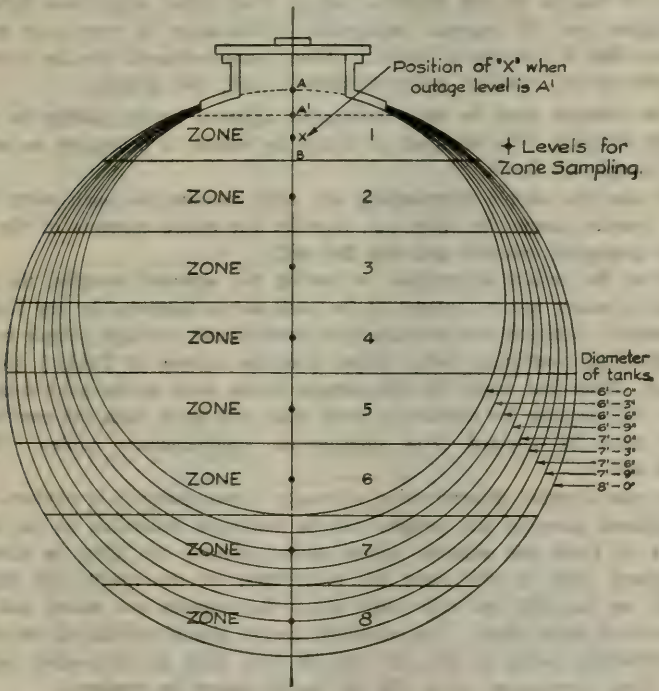

FIG. 1-Z—STANDARD SAMPLING ZONES IN TANK CARS 6 TO 8 FEET IN DIAMETER

5. If the level of liquid in the car is above or at point "A," take the first sample 6 inches below point "A." (A full dome contains 140 gallons; if the dome should be full or substantially full of water, proceed in same manner but add the amount of water contained in dome to the determined amount.) If the liquid is below the point "A," the distance from point "A" to the level of the liquid shall be measured and the first sample taken at a point one-half of the distance from "A*1*" to "B," "B" representing a point 12 inches below "A" and "A*1*" the determined distance from "A" to the level of the liquid. Succeeding samples shall be taken at the center of each 1-foot zone, hence at levels 1 foot 6 inches, 2 feet

6 inches, 3 feet 6 inches, 4 feet 6 inches, 5 feet 6 inches, etc., below "A." The final or lowest sample will in some cases be more and in others less than 6 inches above the bottom of the shell, as will be readily understood from the diagram and tables; and the lower zone therefore varies from 9 inches to 18 inches in depth, but its proper relative weight is cared for accordingly in the tables. Each sample as taken should be immediately transferred to friction top cans, bearing tags indicating the zone numbers, beginning with No. 1 at the top.

Each sample shall be tested separately for water according to the standard method, excepting as follows:

Before measuring the oil in the graduated cylinder, place therein about 200 c.c. of coal-tar solvent naphtha, such as crude xylol, which boils between 100 degrees and 200 degrees Centigrade. (This must be previously tested to insure that it contains no water.) Then measure the oil into the cylinder with the solvent, transfer entire contents to still, and proceed.

The samples must be very thoroughly agitated before taking the portion for analysis. The oil must of course be heated, if necessary, to insure being completely liquid.

In case the sample representing any zone contains so much water that a fair portion cannot be taken out, transfer the entire contents of the can to the graduated cylinder and into the still.

From the results determined on testing the separate samples, the percentage of water in the contents of the tank car is computed by the following method: Multiply the percentage of water found for each sample by the corresponding combining factor taken from the column in Table 1 already selected. Note that where the first sample is not taken at the point 6 inches below "A," because the surface is lower than that point, then the combining factor must be selected from appropriate supplementary tables. (Nos. 2, 3, 4 and 5.)

In case a rapid determination of water is necessary it is obvious that proportioned parts of the samples can be combined according to the same factors to form one sample, whose water content can then be directly determined. But in this event the correctness of the result will depend entirely on the skill and care with which the samples are mixed and the proportional parts taken. The combined sample should consist of ten times the combining factor in c.c., and this in turn must be thoroughly mixed while liquid throughout and a 200 c.c. sample taken for testing.

SIMPLIFIED METHOD FOR TAKING ZONE SAMPLES OF CREOSOTE IN TANK CARS

In many cases a simpler method for zone sampling may be found advantageous. If observation indicates an unusual or excessive amount of free or mixed water, the standard zone sampling method of the Association shall be followed (see above). Otherwise a sampler of the type shown in Fig. 1-S may be used. This shall first be lowered until the point marked "Zone No. 1" is level with the top of the dome, the cover removed and vessel filled at that point, and then slowly withdrawn. This procedure shall be repeated *twice* at point marked "Zone No. 2," and again, once,

Table 1—Combining Factors—Tank Cars Full

Diameter of Tank Car....	6′	6′3″	6′6″	6′9″	7′	7′3″	7′6″	7′9″	8′
1st foot-zone............	11.0	10.3	9.7	9.3	8.7	8.3	8.0	7.5	7.2
2nd foot-zone............	18.2	17.3	16.4	15.5	14.8	14.1	13.4	12.9	12.3
3rd foot-zone............	20.8	19.9	19.0	18.2	17.5	16.7	15.9	15.3	14.7
4th foot-zone............	20.8	20.1	19.5	18.7	18.0	17.5	17.0	16.3	15.8
5th foot-zone............	18.2	18.2	18.0	17.7	17.5	17.0	16.6	16.2	15.8
6th foot-zone............	11.0	14.2	17.4	14.5	14.8	14.9	14.8	14.8	14.7
7th foot-zone............	.....	.....	.....	6.1	8.7	11.5	14.3	12.0	12.3
8th foot-zone............	.....	.....	.....	.....	.....	.....	.....	5.0	7.2

Table 2—Combining Factors—Tank Cars Partly Full
Level 3 Inches Below Top of Shell

Diameter of Tank Car...	6′	6′3″	6′6″	6′9″	7′	7′3″	7′6″	7′9″	8′
1st foot-zone............	9.7	9.1	8.6	8.2	7.7	7.3	7.0	6.6	6.3
2nd foot-zone............	18.4	17.5	16.6	15.6	15.0	14.3	13.6	13.0	12.4
3rd foot-zone............	21.2	20.2	19.2	18.5	17.6	16.9	16.1	15.5	14.8
4th foot-zone............	21.2	20.4	19.7	19.0	18.3	17.7	17.1	16.4	16.0
5th foot-zone............	18.4	18.4	18.2	17.8	17.6	17.1	16.8	16.5	16.0
6th foot-zone............	11.1	14.4	17.7	14.7	15.0	15.1	14.9	14.9	14.8
7th foot-zone............	.....	.....	.....	6.2	8.8	11.6	14.5	12.1	12.4
8th foot-zone............	.....	.....	.....	.....	.....	.....	.....	5.0	7.3

Table 3—Combining Factors—Tank Cars Partly Full
Level 6 Inches Below Top of Shell

Diameter of Tank Car...	6′	6′3″	6′6″	6′9″	7′	7′3″	7′6″	7′9″	8′
1st foot-zone............	7.3	6.8	6.5	6.1	5.8	5.4	5.3	5.0	4.8
2nd foot-zone............	18.9	17.9	17.0	16.0	15.3	14.6	13.8	13.2	12.6
3rd foot-zone............	21.7	20.7	19.7	18.9	18.0	17.2	16.3	15.8	15.1
4th foot-zone............	21.7	20.9	20.2	19.4	18.6	18.0	17.5	16.7	16.2
5th foot-zone............	18.9	18.9	18.6	18.3	18.0	17.5	17.1	16.7	16.2
6th foot-zone............	11.5	14.8	18.0	15.0	15.3	15.5	15.2	15.2	15.1
7th foot-zone............	.....	.....	.....	6.3	9.0	11.8	14.8	12.3	12.6
8th foot-zone............	.....	.....	.....	.....	.....	.....	.....	5.1	7.4

Table 4—Combining Factors—Tank Cars Partly Full
Level 9 Inches Below Top of Shell

Diameter of Tank Car...	6′	6′3″	6′6″	6′9″	7′	7′3″	7′6″	7′9″	8′
1st foot-zone............	4.0	3.8	3.7	3.4	3.2	3.0	2.9	2.7	2.6
2nd foot-zone............	19.6	18.5	17.4	16.5	15.7	14.9	14.2	13.6	13.0
3rd foot-zone............	22.5	21.4	20.3	19.4	18.5	17.6	16.8	16.2	15.4
4th foot-zone............	22.5	21.6	20.8	20.0	19.1	18.5	17.9	17.1	16.5
5th foot-zone............	19.6	19.5	19.2	18.8	18.5	18.0	17.5	17.0	16.5
6th foot-zone............	11.8	15.2	18.6	15.4	15.7	15.8	15.6	15.6	15.4
7th foot-zone............	.....	.....	.....	6.5	9.3	12.2	15.1	12.6	13.0
8th foot-zone............	.....	.....	.....	.....	.....	.....	.....	5.2	7.6

Table 5—Combining Factors—Tank Cars Partly Full
Level 12 Inches Below Top of Shell

Diameter of Tank Car...	6′	6′3″	6′6″	6′9″	7′	7′3″	7′6″	7′9″	8′
2nd foot-zone............	20.4	19.3	18.1	17.1	16.2	15.4	14.6	14.0	13.3
3rd foot-zone............	23.4	22.2	21.0	20.1	19.1	18.2	17.3	16.6	15.8
4th foot-zone............	23.4	22.4	21.6	20.6	19.8	19.1	18.4	17.6	17.0
5th foot-zone............	20.4	20.3	20.0	19.5	19.1	18.5	18.0	17.5	17.0
6th foot-zone............	12.4	15.8	19.3	16.0	16.2	16.3	16.1	16.0	15.8
7th foot-zone............	.....	.....	.....	6.7	9.6	12.5	15.6	12.9	13.3
8th foot-zone............	.....	.....	.....	.....	.....	.....	.....	5.4	7.8

An example of the calculations is shown by the results of tests on samples from car 10463:

G. A. T. X.—10463
(Diameter, 87 inches)

Foot-Zone Sample	Where Taken	Combining Factor (A)	Per Cent Water in Sample (B)	Per Cent of Total Water in Zone (AxB)x1/100 (C)
1	6 in. below shell......	8.3	99.16	8.25
2	1 ft. 6 in. below shell......	14.1	1.98	.28
3	2 ft. 6 in. below shell......	16.7	1.49	.25
4	3 ft. 6 in. below shell......	17.5	1.16	.20
5	4 ft. 6 in. below shell......	17.0	1.21	.21
6	5 ft. 6 in. below shell......	14.9	1.15	.17
7	6 ft. 6 in. below shell......	11.5	1.11	.13
	Total..............	....	....	9.49

at point marked "Zone No. 3." The four samples shall then be combined and mixed at once, while the oil is thoroughly liquid—no sample shall be taken for analysis from oil which contains crystals.

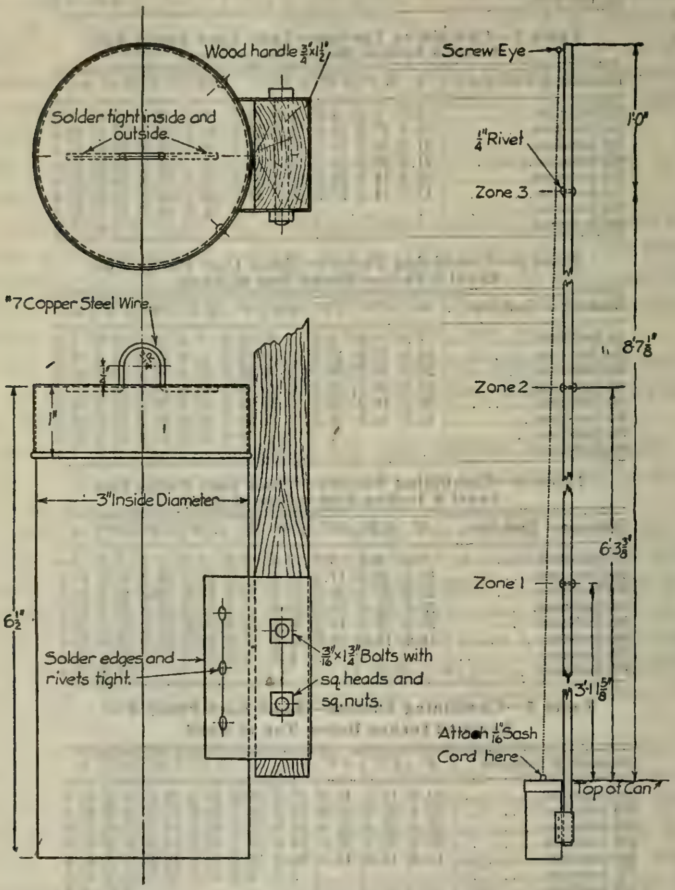

FIG. 1-S—SUBSTITUTE ZONE SAMPLING APPARATUS

[8]SPECIFICATIONS FOR CREOSOTE ANALYSIS

(1) WATER

Apparatus

A vertical, cylindrical copper still, with removable flanged top, and yoke, of the form and approximate dimensions shown in Fig. 2, shall be used.

Method

When any measurable amount of water is present in the distillate below 210 degrees, on testing in accordance with Section 4, Distillation, the oil and water in this fraction shall be separated, if possible, and measured separately. If more than 2 per cent of water is present, or if the water is apparently present to an extent in excess of 2 per cent, but an accurate separation is impossible, the percentage of water present shall be determined by the following method, and the water-free oil so obtained shall be used in distillation test, as described under Section 4.

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[8] Adopted, Vol. 18, 1917, pp. 1262, 1577; Vol. 20, 1919, pp. 127, 840; Vol. 27, 1926, pp. 940, 1414; Vol. 28, 1927, pp. 1118, 1427.

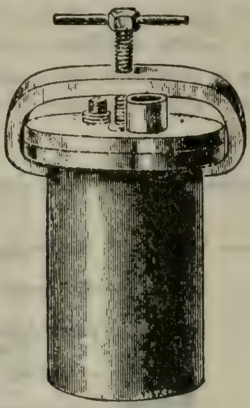


FIG 2—COPPER STILL

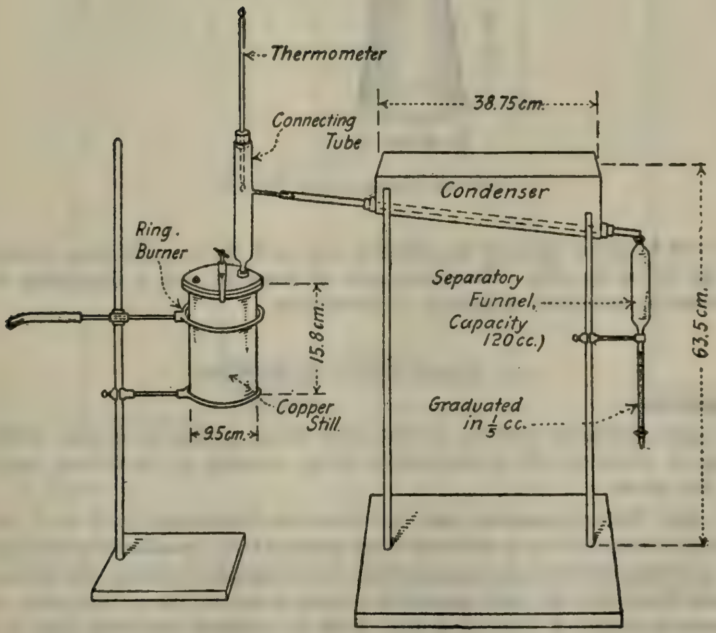


FIG. 3—ASSEMBLED APPARATUS FOR WATER TEST

Measure 200 c.c. of oil in graduated cylinder, and pour into copper still (Fig. 2 and 3), allowing the cylinder to drain into the still for several minutes. Attach lid and clamp, using a paper gasket slightly wet with oil around the flange of the still. Apply heat by means of the ring burner, which should be placed just above the level of the oil in the still at the beginning of the test, and gradually lowered when most of the water has distilled over. Continue the distillation until the vapor temperature indicated by the thermometer with the bulb opposite the offtake of the connecting tube reaches 205 degrees Centigrade. Collect distillate in separatory funnel.

When the distillation is completed, and a clear separation of water and oil in the funnel has taken place, the water is read by volume and drawn off, and whatever light oil has distilled over with the water is then returned to the oil in the still. The dehydrated oil from the still is then taken for distillation, described in Section 4, Distillation.

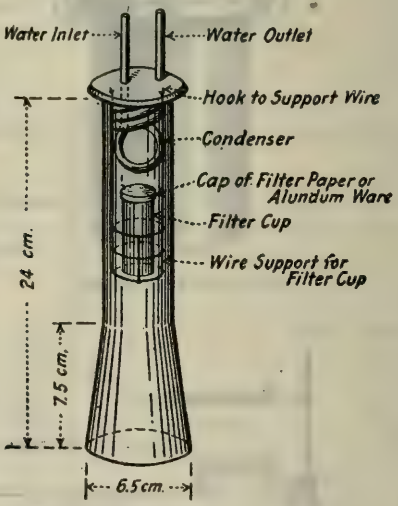


Fig. 4—Extraction Flask

(2) INSOLUBLE IN BENZOL

Apparatus

(a) Extractor may be of the form shown in Fig. 4, or any similar form in which the oil is subjected to direct washing by the boiling vapors of the solvent.

(b) Filtering medium may be either two thicknesses of S. & S. No. 575 or Whatman No. 5 hardened filter paper, 15 cm. in diameter, arranged in cup-shape by folding symmetrically; or alundum thimbles, flat bottom, 30x80 R.A. 98. If filter papers are used, prior to using they shall be soaked in benzol to remove grease, dried in a steam oven and kept in a dessicator until ready to be used. The filter-paper cup may be suspended in the extractor flask by a wire basket hung from two small hooks on the under surface of the metal cover of the flask.

If the alundum thimble is used, it may be supported by making two perforations in the top of the thimble, and suspending from the cover by German silver or platinum wires.

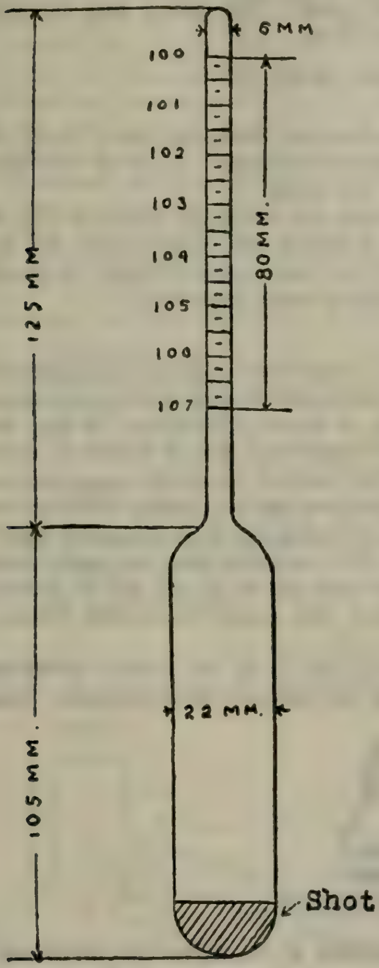


Fig 5—Hydrometer

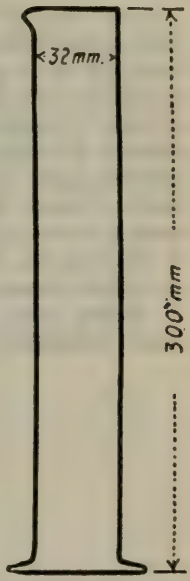


Fig. 6—Specific Gravity Cylinder

Method

Weigh 10 grams of dry oil in 100 c.c. beaker. Add about 50 c.c. of pure benzol, and transfer at once to the filter cup. The filter cup or thimble is previously weighed, and the paper cup shall always be kept in a weighing bottle until ready for use. Wash out the beaker with benzol, passing all washings through the filter cup, and place the latter at once in the extraction apparatus.

Extractor shall contain a suitable quantity of pure benzol. Sufficient heat to boil the solvent shall be provided by means of an electric heater or a steam bath.

Continue the extraction until the descending solvent is practically colorless, and remove the filter cup and dry in steam oven until all solvent is driven off; cool in desiccator and weigh. The balance used for this purpose should be accurate to within 0.5 mg.

(3) SPECIFIC GRAVITY

Apparatus

(a) Hydrometer shall be of the form and dimensions shown in Fig. 5. It shall be standardized at 15.5 degrees Centigrade. A set of two with ranges 1.00 to 1.08 and 1.07 to 1.15 will suffice.

(b) Cylinder shall be of the form and dimensions shown in Fig. 6.

(c) If a very accurate method is desired, the specific gravity may be determined by means of a pycnometer or specific gravity bottle, as shown in Fig. 7, having a capacity of at least 25 cubic centimeters.

Method

(a) The oil shall be brought to a temperature of 38 degrees Centigrade (100 degrees Fahr.), and the determination shall be made at that temperature unless the oil is not entirely liquid at 38 degrees Centigrade. In case the oil requires to be brought to a higher temperature than 38 degrees in order to render it completely fluid, it shall be tested at the lowest temperature at which it is completely fluid, and a correction made by adding 0.0008 to the observed specific gravity for each degree Centigrade above 38 degrees Centigrade at which the test is made. This correction does not apply with equal accuracy to all oils, but serious error, due to its use, will be avoided if the foregoing precaution is observed, with respect to avoiding unnecessarily high temperature.

Before taking the specific gravity, the oil in the cylinder should be stirred thoroughly with the glass rod, and this rod, when withdrawn from the liquid, should show no solid particles at the instant of withdrawal. Care should be taken that the hydrometer does not touch the sides or bottom of the cylinder when the reading is taken, and that the oil surface is free from froth and bubbles.

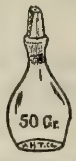


Fig. 7—Pycnometer

(b) Weigh the pycnometer empty, then fill with recently distilled water and weigh at 38 degrees Centigrade. Empty the pycnometer and then fill with water-free oil at 38 degrees Centigrade, and weigh. The specific gravity 38/15.5 degrees Centigrade is then calculated as below:

The expression "38/15.5 Centigrade" means specific gravity taken at 38 degrees Centigrade compared with water at 15.5 degrees

Centigrade. This cannot be determined directly. The specific gravity is first determined at 38 degrees Centigrade compared with water at 38 degrees Centigrade, and this determination represents the relation of the weight of a volume of oil at 38 degrees Centigrade to the weight of an equal volume of water at the same temperature. The relation of an equal volume of water at 15.5 degrees Centigrade is obtained by multiplying the former figure by .99393, the density of water at 38 degrees Centigrade compared to water at 15.5 degrees Centigrade.

From the foregoing it will be readily seen that it is incorrect to calculate the specific gravity at 38/15.5 degrees Centigrade, by dividing the weight of oil taken at 38 degrees Centigrade by the weight of water taken at 15.5 degrees Centigrade. An example is given herewith of the correct and incorrect methods of calculating; where the weight of a specific gravity bottle is 23.7531, the weight of the bottle filled with water up to the mark at 15.5 degrees Centigrade is 78.3600; the weight of the bottle plus water at 38 degrees Centigrade is 78.1128; the weight of the bottle filled with oil at 38 degrees Centigrade is 80.2755. The correct calculation, therefore, would be as follows:

Specific gravity at 38/15.5 degrees Centigrade =

$$\frac{80.2755 - 23.7531}{78.1128 - 23.7531} = 1.0398$$

Corrected to 38/15.5 degrees Centigrade:

$$1.0398 \times \frac{.99299 \text{ (D. water 38 degrees Centigrade)}}{.99905 \text{ (D. water 15.5 degrees Centigrade)}} = 1.03355$$

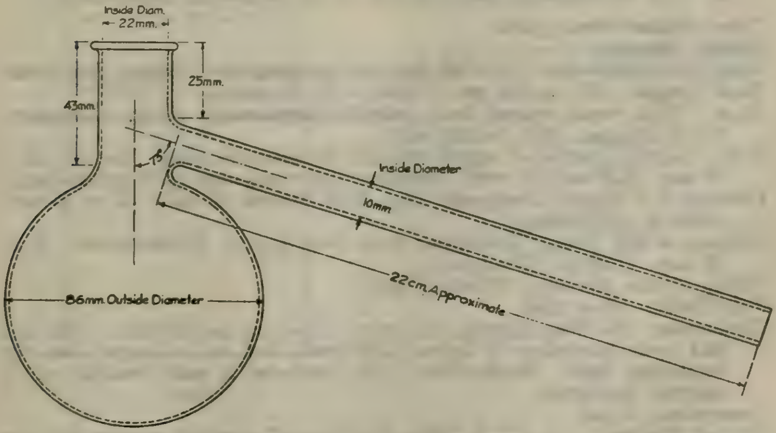
The incorrect method of calculation is as follows:

$$\frac{80.2755 - 23.7531}{78.3600 - 23.7531} = 1.0351.$$

(4) DISTILLATION

Apparatus

(a) Flask shall be of the form and dimensions shown in Fig. 8.



[9]Fig. 8—Flask for Distillation

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[9] Adopted, Vol. 27, 1926, pp. 938, 1414; Vol. 28. 1927, pp. 1118, 1427.

(a) Flask.—The distillation flask, Fig. 8, shall be a side neck distilling flask, having the following dimensions:

Diameter of bulb (outside)........	86 mm.	± 1.5 mm.
Diameter of neck (inside)..........	22 “	± 1.0 “
Diameter of tubulature (inside)......	10.0 “	± 0.5 “
Length of neck....................	43 “	± 1 “
Distance, top of neck to tubulature...	25 “	± 1 “
Angle of tubulature................	73 deg.	± 1 deg.
Length of tubulature...............	22 cm.	± 0.5 cm.

(b) Condenser Tube—The condenser tube shall be a suitable form of tapered glass tubing of the following dimensions:

Diameter of small end....	12.5 mm.	Permissible variation ± 1.5 mm.
Diameter of large end....	28.5 “	Permissible variation ± 3.0 “
Length	360.0 “	Permissible variation ± 4.0 “

Fig. 9—Condenser Tube

(c) Shield.—A galvanized-iron shield lined with one-eighth-inch asbestos of the form and dimensions shown in Fig. 10 shall be used to protect the flask from air currents and to prevent radiation. The cover (top) shall be of transit board made in two parts, or it may be of galvanized iron lined with one-eighth-inch asbestos.

(d) Receivers (Erlenmeyer flask) of 50 to 100 c.c. capacity are most convenient form.

Thermometers should conform to the following specifications:[10]

(e) 1. These specifications cover a total-immersion thermometer graduated in Centigrade degrees as specified, the range being 0 to 400 degrees Centigrade.

2. The purpose of these specifications is to provide a thermometer for distillation tests within these ranges.

3. The thermometer shall conform to the following requirements:

Type: Etched stem, glass.
Liquid: Mercury.
Range and Subdivision: 0 to 400 degrees Centigrade in 1 degree Centigrade.
Total Length: 378 to 384 mm. (14.88 to 15.12 inches).
Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 inch).
Bulb: Corning normal or equally suitable thermometric glass. Length, 10 to 15 mm. (0.39 to 0.59 inch). Diameter, 5.0 to 6.0 mm. (0.20 to 0.24 inch).
Distance to 0 Degree Centigrade Line from Bottom of Bulb: 25 to 35 mm. (0.98 to 1.38 inches).
Distance to 400 Degree Centigrade Line from Top of Thermometer: 30 to 45 mm. (1.18 to 1.77 inches).
Filling Above Mercury: Nitrogen gas.
Top Finish: Glass ring.
Graduation: All lines, figures, and letters clear cut and distinct. The first and each succeeding 5 degree Centigrade line to be longer than the remaining lines. Graduations to be numbered at each multiple of 10 degrees Centigrade.
Immersion: Total.
Special Marking: “A.S.T.M. High Distillation,” a serial number and the manufacturer's name or trade mark shall be etched on the stem.

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[10] Adopted, Vol. 26, 1925, pp. 71, 1252; Vol. 27, 1926, pp. 946, 1414.

Scale Error: The error at any point of the scale up to 370 degrees Centigrade when the thermometer is standardized, as provided below, shall not exceed 1 degree Centigrade.

Standardization: The thermometers shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 50 degrees Centigrade up to 370 degrees Centigrade.

Test for Permanency of Range: After being subjected to a temperature between 360 to 370 degrees Centigrade for 24 hours, the accuracy shall be within the limit specified.

Case: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. High Distillation, 0 to 400 deg. C."

NOTE—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

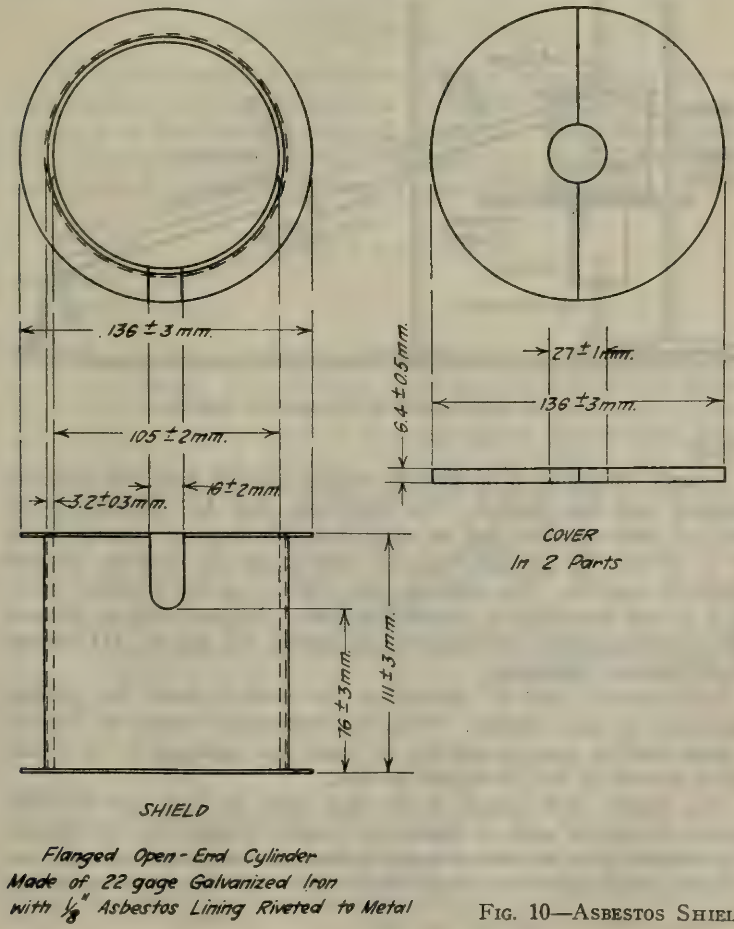
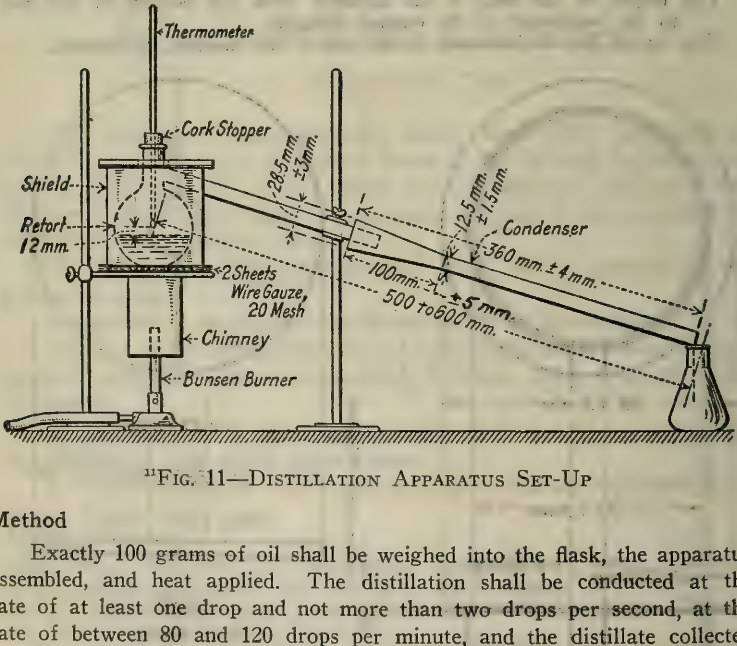


FIG. 10—ASBESTOS SHIELD

The flask shall be supported on a tripod or rings over two sheets of 20-mesh gauze, 6 inches square. It shall be connected to the condenser tube by a tight cork joint. The thermometer shall be inserted through a cork in the tubulature with the bottom of the bulb ½ inch from the surface of the oil in the flask. The exact location of the thermometer bulb shall be determined by placing a vertical rule graduated in divisions not exceeding $\frac{1}{16}$ inch back of the flask when the latter is in position for the test, and sighting the level of the liquid and the point for the bottom of the thermometer bulb. The distance from the bulb of the thermometer to the outlet end of the condenser tube shall be not more than 24 nor less than 20 inches. The burner shall be protected from draughts by a suitable shield or chimney (Fig. 11).



[11]Fig. 11—Distillation Apparatus Set-Up

Method

Exactly 100 grams of oil shall be weighed into the flask, the apparatus assembled, and heat applied. The distillation shall be conducted at the rate of at least one drop and not more than two drops per second, at the rate of between 80 and 120 drops per minute, and the distillate collected in weighed receivers. The condenser tube shall be warmed whenever necessary to prevent accumulation of solid distillates. Fractions shall be collected at the following points: 210 degrees, 235 degrees, 270 degrees, 315 degrees, and 355 degrees Centigrade.

The receivers shall be changed as the mercury passes the dividing temperature for each fraction. When the temperature reaches 355 degrees, the flame shall be removed and any oil which has condensed in the offtake shall be drained in the 355 degree fraction.

The residue shall remain in the flask with the cork and the thermometer in position until no vapors are visible; it shall then be weighed. If the residue is to be further tested it shall then be poured directly into the brass collar used in the float test or into a tin box and covered and allowed to cool to air temperature. If the residue becomes so cool that it cannot be poured readily from the flask, it shall be re-heated by holding the bulb of the flask in hot water or steam, and not by the application of flame.

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[11] Adopted, Vol. 27, 1926, pp. 916, 1414.

For weighing the receivers and fractions, a balance accurate to at least 0.05 gram shall be used.

During the progress of the distillation the thermometer shall remain in its original position. No correction shall be made for the emergent stem of the thermometer.

When any measurable amount of water is present in the distillate, it shall be separated as nearly as possible and reported separately, all results being calculated on a basis of dry oil. When more than 2 per cent of water is present, water-free oil shall be obtained by separately distilling a larger quantity of oil, returning to the oil any oil carried over with the water, and using dried oil for final distillation. (See Section 1, Water.)

(5) SPECIFIC GRAVITY OF FRACTIONS

As specific gravity is an absolute physical determination, any recognized method which can be applied to the quantity and quality of material at hand to be tested must be considered satisfactory. The following methods are recommended as convenient and accurate means for the relatively small amounts of oil available in determining gravity of fractions to be tested.

LIQUID FRACTIONS

Apparatus

Westphal balance.

Method

If the fraction to be tested is liquid at a temperature not exceeding 60 degrees Centigrade, the Westphal balance can be used with convenience and rapidity. A special type of Westphal balance is obtainable, designed for testing very small quantities. However, the ordinary type Westphal balance can be adapted to testing small fractions by the use of a special plummet. This can be readily made in the laboratory from a piece of ordinary glass tubing 7 mm., outside diameter, sealed at the end, and melting into the glass where sealed a short platinum wire.

After cooling, place 9 to 10 grams of mercury in the tube, making a column 35 to 40 mm. high. Seal off the tube within 20 mm. of the top of the mercury column with blowpipe flame. The plummet shall have a length of about 55 to 60 mm. over all, and should weigh between 10 and 12 grams.

SOLID AND SEMI-SOLID FRACTIONS

Methods

Special platinum or nickel pan as shown in Fig. 12.

For the determination of fractions that are solid and semi-solid and cannot readily be liquefied at a temperature not exceeding 60 degrees Centigrade, a weighing pan constructed of platinum or nickel may be used.

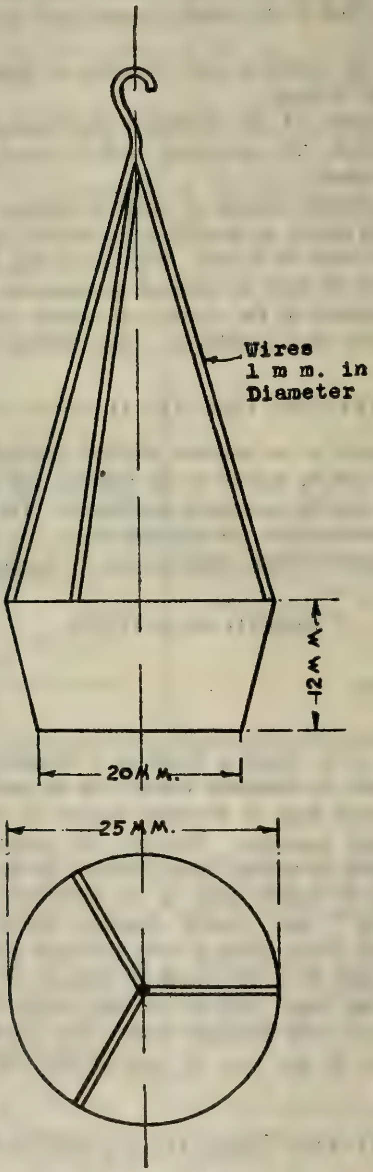

Fig. 12—Weighing Pan

A pan of convenient dimensions is 20 mm. diameter at the base and 25 mm. diameter at the top, and about 12 mm. deep. It is made of platinum and supported by three platinum wires 1 mm. in diameter, and has a total weight of about 7 grams.

Solid or semi-solid fractions of oil can be rapidly and accurately tested in this apparatus by the usual method of weighing in air and in water. The usual precaution, of igniting the pan before use, avoiding the enclosure of air or water in the sample, should be observed.

Note—The method for liquid fractions is usually applicable to the fractions 235 to 315 degrees Centigrade and the method for solid and semi-solid fractions to the fraction 315 to 355 degrees Centigrade.

[12](6) FLOAT TEST

The residue remaining in the flask after the distillation on test shall remain until it reaches a temperature between 100 and 125 degrees Centigrade. The consistency of the residue shall then be determined as follows:

Float

The float shall be made of aluminum alloy and shall be in accordance with the following requirements:

	Minimum	*Normal*	*Maximum*
Weight of float, grams	37.70	37.90	38.10
Total height of float, mm	34.0	35.0	36.0
Height of rim above lower side of shoulder, mm.	26.5	27.0	27.5
Thickness of shoulder, mm	1.3	1.4	1.5
Diameter of opening, mm	11.0	11.1	11.2
Height of rim above water with load of 5.5 grams, mm.	7.0	8.5	10.0

Collar

The collar shall be made of brass and shall be in accordance with the following requirements:

	Minimum	*Normal*	*Maximum*
Weight of collar, grams	9.6	9.8	10.0
Over-all height of collar, mm	22.3	22.5	22.7
Inside diameter at bottom, mm	12.72	12.82	12.92
Inside diameter at top, mm	9.65	9.70	9.75

The top of the collar shall screw up tightly against the lower side of the shoulder.

Assembly

The assembled float and collar, with the collar filled flush with the bottom and weighed to a total weight of 53.2 grams, shall float upon water with the rim 8.5 ± 1.5 mm. above the surface of the water. Dimensions of the apparatus additional to those required above are given in Fig. 13.

Thermometer

The thermometer shall conform to the following specifications:

Type: Etched stem, glass.
Liquid: Mercury.
Range and Subdivision: —2 to +80 degrees Centigrade in 0.2 degrees Centigrade.

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[12] Adopted, Vol. 26, 1925, pp. 67-70, 1252; Vol. 27, 1926, pp. 951, 1414.

Total Length: 378 to 384 mm. (14.88 to 15.12 inches).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 inches).

Bulb: Corning normal or equally suitable thermometric glass. Length, 9 to 14 mm. (0.35 to 0.55 inch). Diameter, 4.5 to 5.5 mm. (0.18 to 0.22 inch).

Distance to 0 Degree Centigrade Line from Bottom of Bulb: 75 to 90 mm. (2.95 to 3.54 inches).

Distance to 80 Degrees Centigrade Line from Top of Thermometer: 30 to 45 mm. (1.18 to 1.77 inches).

Expansion Chamber: To permit heating the thermometer at least 50 degrees Centigrade above highest temperature on scale.

Filling above Mercury: Nitrogen gas.

Top Finish: Glass ring.

Graduation: All lines, figures, and letters clear cut and distinct. Each whole degree Centigrade line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2 degrees Centigrade.

Immersion: Total.

Special Marking: "A.S.T.M. Low S.P.," a serial number and the manufacturer's name or trade mark shall be etched on the thermometer.

Scale Error: The error at any point of the scale when the thermometer is standardized as provided below, shall not exceed 0.2 degrees Centigrade.

Standardization: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 20 degrees Centigrade.

Case: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Low S.P., 0 to 80 degrees Centigrade."

Note—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

Bath

The diameter of the bath and the depth of water shall be at least 185 mm.

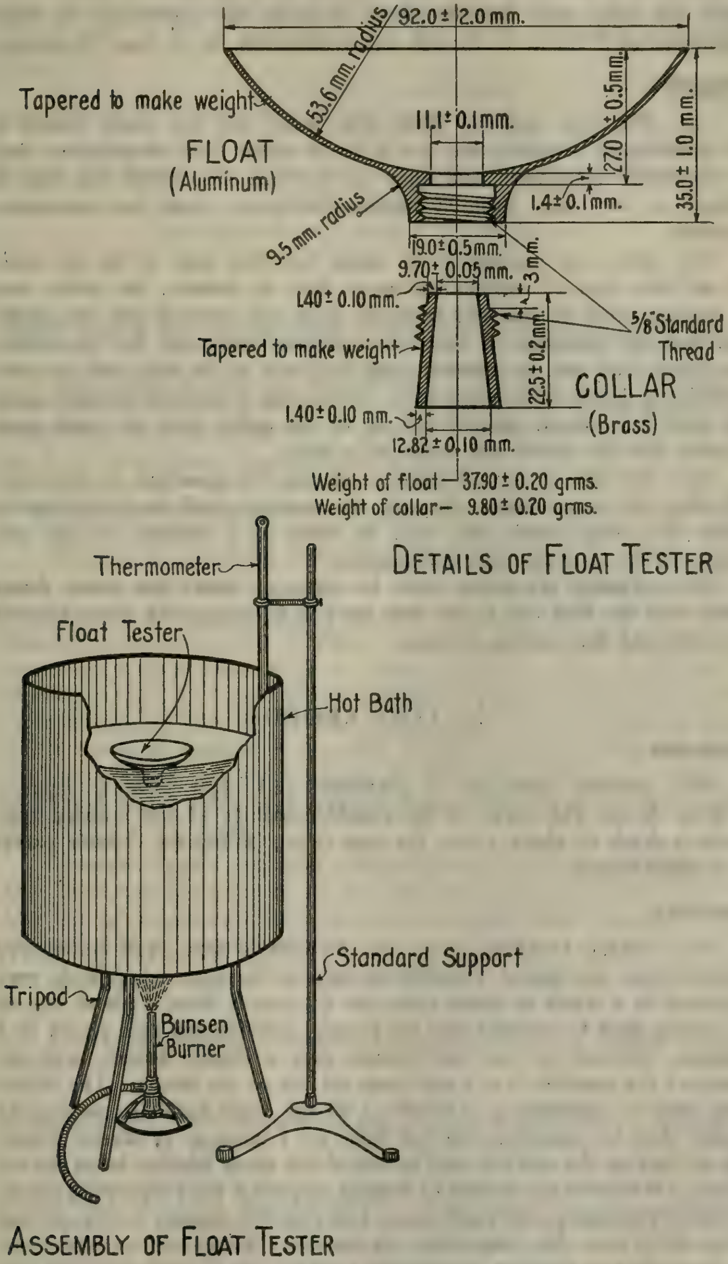
Preparation of Sample

The brass collar shall be placed with the smaller end on a brass plate which has been previously amalgamated with mercury by first rubbing it with a dilute solution of mercuric chloride or nitrate, and then with mercury.

The sample shall be completely melted at the lowest possible temperature that will bring it to a sufficiently fluid condition for pouring, excepting creosote oil residues, which shall be mixed and poured at a temperature of 100 to 125 degrees C. It shall be stirred thoroughly until it is homogeneous and free from air bubbles. The sample shall then be poured into the collar in any convenient manner until slightly more than level with the top.

Tar Products

Tar products shall be poured at a temperature of 100 to 125 degrees Centigrade and immediately immersed in ice water maintained at 5 degrees Centigrade for 5 minutes, after which the surplus material shall be removed



DETAILS OF FLOAT TESTER

ASSEMBLY OF FLOAT TESTER

FIG. 13

by means of a spatula or steel knife, which has been slightly heated. The collar and plate shall then be placed in a tin cup containing ice water maintained at 5° C. ± 1° C., and left in this bath for at least 15 minutes.

Procedure

(a) The bath shall be filled with water and the water heated to the temperature at which the test is to be made. This temperature shall be accurately maintained and shall at no time throughout the test be allowed to vary more than 0.5 degrees Centigrade from the temperature specified.

(b) After the material to be tested has been kept in the ice water for not less than 15 minutes nor more than 30 minutes, the collar with its contents shall be removed from the plate and screwed into the aluminum float and immersed in water at 5 degrees Centigrade for one minute. Any water shall then be removed from the inside of the float and the latter immediately floated in the warm bath. As the plug of material becomes warm and fluid, it is forced upward and out of the collar until the water gains entrance into the saucer and causes it to sink.

(c) The time in seconds between placing the apparatus on the water and when the water breaks through the material shall be determined by means of a stop watch, and shall be taken as a measure of the consistency of the material under examination.

Note—Special precaution shall be taken to insure the collar fitting tightly into the float and to see that there is no seepage of water between the collar and float during the test.

[13](7) COKE RESIDUE

Apparatus

The crucible shall be of platinum and shall have a capacity of 20 to 30 cc. The cover of the crucible shall be of the inverted type, having a depth of about 1 cm., the wall tightly fitting the crucible except for a slight crease.

Procedure

The residue resulting from the distillation test shall be poured directly into the tarred crucible or into a tin box, wherein it may be heated on a water or steam bath, but not over a flame. About 1 g. of the residue shall be weighed into the covered crucible and then placed on a platinum, nichrome, or fire-clay triangle over a Bunsen burner, with the bottom of the crucible 6 to 8 cm. from the top of the burner. The burner flame shall be regulated to a height of 20 cm. while burning free and the crucible shall be exposed to the full flame for 7 minutes. A Meeker burner may be used, or the crucible may be heated for seven minutes in an electric furnace. Whatever the method of heating employed, the temperature during the entire 7-minute period shall be not less than 950 degrees Centigrade and should be as near that temperature as possible. At the end of this period the flame shall be removed, the crucible transferred to a desiccator and permitted to cool, after which it shall be weighed. The residue in the crucible after ignition shall be reported as "fixed carbon" (i. e., coke).

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[13] Adopted, Vol. 27, 1926, pp. 918, 1414.

The test shall be conducted in a part of the laboratory free from draughts.

The percentage of coke obtained in accordance with Section 2 shall be calculated on the basis of the original sample of oil.

Example—With a retort distillation of 15.9 per cent of residue at 355 degrees Centigrade, the residue containing 7.2 per cent of fixed carbon:

$$\text{Coke in oil} = \frac{15.9 \times 7.2}{100} = 1.14 \text{ per cent.}$$

[14]METHODS OF CHEMICAL ANALYSIS OF ZINC CHLORIDE

These methods cover the determination of the percentages of insoluble basic zinc chloride, zinc chloride, and iron present in commercial concentrated solution of zinc chloride or in fused or granulated zinc chloride, for use in the preservative treatment of wood.

PREPARATION AND STANDARDIZATION OF SOLUTIONS

Standard Ferricyanide Solution.—Weigh out 43.25 g. of c.p. potassium ferricyanide and 14 g. of c.p. crystallized sodium sulphite, dissolve in water and make up to 1 liter at room temperature. Shake thoroughly. Standardize against a zinc solution of known concentration prepared from spelter of known zinc content or from c.p. zinc oxide which has been previously ignited. One cubic centimeter of this solution will be equal to approximately 0.01 g. of zinc. The standardization should be carried out as nearly as possible in the same manner as in the estimation of zinc and approximately the same amount of zinc should be present. Keep the solution in a dark bottle. Shake thoroughly before each using and standardize each time it is used.

Uranium Acetate Indicator.—Dissolve 4.4 g. of c.p. uranium acetate, free from sodium, in 100 cc. of hot water and 2 cc. of glacial acetic acid. Use this as an external indicator on a paraffined plate, making the drops as nearly 0.05 cc. as possible.

Hydrogen Peroxide.—The usual laboratory reagent is satisfactory, if fresh.

Hydrogen Sulphide Solution.—The usual laboratory reagent is satisfactory.

DETERMINATION OF INSOLUBLE OR BASIC ZINC CHLORIDE

Weigh from 10 to 14 g. of the sample, if fused or granulated, from a stoppered weighing bottle, or place an equivalent quantity, if a solution, into a 600-cc. beaker. Add cold water to 400 cc. Stir the contents of the beaker until solution is complete. Allow to settle over night. Filter the solution through a 12.5-cm. filter paper which has previously been washed, dried and weighed. Receive filtrate in a 1000-cc. graduated measuring flask. Policeman the beaker, and wash the insoluble matter in the filter paper until the filtrate measures 1 liter. Dry the filter paper containing the insoluble matter over night in an oven heated to 100 degrees Centigrade (212 degrees Fahr.). Cool and weigh between clipped watch glasses. Calculate the increase in weight of filter paper to a percentage of the original sample.*

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[14] Adopted. Vol. 26. 1925 pp. 72-74, 1252; Vol. 27, 1926, pp. 955, 1414.

Duplicate determinations should check within 1.3 per cent.

DETERMINATION OF ZINC

(a) *Volumetric method.* (For use when manganese chloride does not exceed 0.3 per cent.)

The filtrate obtained from the estimation of insoluble basic zinc chloride and whose volume is exactly 1 liter is shaken and three aliquot portions of 100 cc. each are taken with an accurate 100-cc. pipette and transferred into 450-cc. Griffins beakers. Add to each portion 15 g. of ammonium chloride and 5 cc. of concentrated hydrochloric acid. Dilute to 350 cc. and heat nearly to boiling. Titrate slowly with vigorous stirring, using a solution of potassium ferrocyanide as the standard reagent and uranium acetate as an external indicator. The average of the three aliquot portions should be reported.

(b) Volumetric Method. (For use when the manganese chloride equals or exceeds 0.3 per cent.)

To the aliquot portions taken as described under (*a*), 1 cc. of hydrogen peroxide (2 to 3 per cent) and 10 cc. of ammonia (1:1) shall be added. Stand on steam bath until settled. Filter off the manganese, wash beaker and paper twice with hot water. Dissolve the precipitate in the smallest amount of hydrochloric acid (1:1) in the original beaker, heat until all is dissolved; the volume of the solution should be about 20 cc. Reprecipitate the manganese with 1 cc. of hydrogen peroxide and 10 cc. of ammonia, boil, filter, and wash several times with hot water. Add the filtrate to that obtained in the first separation. Add 15 cc. of concentrated hydrochloric acid to the combined filtrate and just neutralize with concentrated ammonia, then add 5 cc. of hydrochloric acid in excess. Dilute to 325 cc. and add 25 cc. of saturated hydrogen sulphide water to remove any traces of hydrogen peroxide, heat and titrate as in (*a*).

(*c*) *Gravimetric Method.* (Alternate method, for use when only a limited amount of work is necessary.)

The filtrate obtained from the estimation of insoluble basic zinc chloride and whose volume is exactly 1 liter is shaken and three aliquot portions of 200 cc. each are taken with an accurate pipette and transferred to 450-cc. Griffins beakers. Add to each 4 cc. of concentrated c.p. sulphuric acid. Evaporate on a steam bath; then on a steam plate or hot plate to copious SO_3 fumes, to completely eliminate chlorides.

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*A Gooch crucible may be used in place of the weighed filter paper.

Cool and take up in 100 cc. of hot distilled water. Add 0.5 g. of aluminum powder. Cover with a watch glass. Heat to boiling and boil 5 minutes. Filter through an 11-cm. filter paper. Receive the filtrate in a covered 1000 cc. Griffins beaker. Wash the beaker and filter thoroughly with hot water until a drop of methyl orange indicator placed behind the double fold of filter paper shows no acidity. Exactly neutralize the filtrate with dilute ammonia. Use great care and precision, and carry the neutralization just to the end point.

Add 10 cc. of 0.1 N sulphuric acid (3 cc. of concentrated c.p. sulphuric acid in 1000 cc. of water). Dilute to 650 cc. Cover the beaker, and bubble a rapid stream of hydrogen sulphide for one-half to one hour at room temperature.

Settle and filter through a double filter of one 15-cm. and one 11-cm. paper* folded together. Transfer the precipitate to the filter paper. Thoroughly policeman the beaker until the zinc sulphide is all removed except a very thin film which clings tenaciously to the glass at the surface of the liquid. Thoroughly wash the beaker and precipitate at room temperature with water saturated with hydrogen sulphide. Repeat washing of filter paper and precipitate five or six times. Transfer paper and precipitate to an ignited, cooled, desiccated and weighed porcelain crucible of suitable capacity (about 25 to 30 cc.). Carefully dry the paper and precipitate and when dry completely burn off the paper at as low a temperature as possible. When carbon has been completely burned out, ignite the resultant oxide of zinc strongly to as high a temperature as is available, but not higher than can be attained with a laboratory blast lamp with the aid of gas and air. Heat for 30 minutes. After strong ignition, cool the crucible, desiccate and weigh. The increase in weight is zinc oxide. The weight of the zinc oxide multiplied by the factor 1.6749, multiplied by 100, divided by the weight of sample in the aliquot portion taken, equals the percentages of zinc chloride.

The average of the results obtained with the three aliquot portions analyzed shall be reported. Results should agree within 1.5 per cent.

ESTIMATION OF IRON AND ALUMINA

Weigh 10 g. of the sample, if fused or granulated, or place an equivalent quantity, if a solution, into a suitable beaker and dissolve in 100 cc. of water or dilute to 100 cc., if a solution. Add sufficient hydrochloric acid to dissolve any basic zinc chloride. Add a slight excess of bromine water and boil off excess. Neutralize with a weak solution of sodium carbonate until a permanent precipitate of zinc carbonate is obtained. Add three drops of glacial acetic acid and 2 g. of sodium acetate, and boil. Filter and wash. Redissolve the precipitate in the original beaker with hot hydrochloric acid (1:1). Reprecipitate the iron and alumina with a slight excess of ammonia, filter and wash free from chlorine. Ignite in a platinum crucible and weigh as $Fe_2O_3 + Al_2O_3$.

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*Ashless paper should be used.

[15]METHOD FOR DETERMINING THE STRENGTH OF ZINC CHLORIDE SOLUTION

Use

This method is for the control of the strength of the zinc chloride solutions as used in actual treatment, and not for the analysis of the concentrated zinc chloride as purchased.

Principle.—The chlorine is determined by titration with standard silver nitrate solution and then calculated into zinc chloride according to the following equation:

$$2AgNO_3 + ZnCl_2 = 2AgCl + Zn\,(NO_3)_2.$$

Standard Silver Nitrate Solution.—1/10 normal silver nitrate per liter of distilled water.

Indicator.—Neutral potassium Chromate, K_2CrO_4 (Chlorine free), saturated solution, 60 grams in 100 cc. of distilled water.

Method of Procedure

(a) *Specific Gravity.*—A quantity of zinc chloride to be tested, sufficient to float the hydrometer, is filtered into a hydrometer cylinder. Filtration is unnecessary if the solution is perfectly clear and free from Creosote Oil. The specific gravity of the filtered solution at 70 degrees Fahr. is then determined by means of a hydrometer having a scale reading from 1.000 to 1.060.

(b) *Titration.*—Two (2) cc. of the filtered zinc chloride solution are introduced into a 500 cc. Erlenmeyer flask by means of an accurately calibrated pipette and diluted to about 100 cc. with distilled water. After adding two (2) drops of the potassium chromate indicator the solution is titrated with the standard silver nitrate solution, using a 50 cc. glass-stoppered burette accurately graduated to tenths of a cubic centimeter. The silver nitrate solution is slowly run into the flask until the solution in the flask just begins to assume a permanent reddish tinge, the flask having been gently shaken after each addition of silver nitrate.

(c) *Calculation.*—The per cent strength of the zinc chloride solution is calculated according to the following equation:

$$\frac{cc.\ AgNO_3 \times gm.\ AgNO_3\ per\ cc.}{cc.\ ZnCl_2 \times Sp.\ Gr.\, ZnCl_2} \times 100 \times .401 = \%\ \text{Strength}\ ZnCl_2$$

In this equation, the symbols signify the following:

$AgNO_3$ = Silver Nitrate; $ZnCl_2$ = Zinc Chloride;

$$0.401 = \frac{136.31}{2 \times 169.96} = \frac{ZnCl_2}{2AgNO_3}$$

Grams $AgNO_3$ per cc. = Strength of the standard silver nitrate solution.

Example: Strength of $AgNO_3$.................... .017 gr. per cc.
cc. of $AgNO_3$ used.................... 8.2
cc. of $ZnCl_2$.......................... 2.0
Sp. Gr. $ZnCl_2$........................ 1.024

$$\frac{8.2 \times .017}{2 \times 1.024} \times .401 \times 100 = 2.72\% = ZnCl_2$$

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[15] Adopted, Vol. 20, 1919, pp. 133, 841; Vol. 27, 1926, pp. 958, 1414.

The strength of the standard silver nitrate solution should be approximately 1/10 normal or 16.996 grams $AgNO_3$ per liter. The *exact* strength of the solution must be known and should be indicated on the bottle.*

(d) *Precautions.*—As the above method is based on the estimation of the chlorine in the zinc chloride, it is essential to determine whether the water used in making up the zinc chloride solutions at the treating plant contains chlorides, and if so to make the proper deductions. Two (2) cc. of the water should be titrated exactly as described above. The number of cc. of standard silver nitrate solution required to produce the color change should be noted, and this amount should always be deducted from the number of cc. of silver nitrate solution required for the titration of the zinc chloride solution sample before making calculations. Where the chlorine content of the water used is found to be variable check determinations should be made.

[16]DIRECTIONS FOR THE USE OF IODINE POTASSIUM FERRICYANIDE STARCH COLOR REACTION TEST FOR DETERMINING ZINC CHLORIDE PENETRATION

This method requires the following chemicals and apparatus:

(1) Potassium Ferricyanide.
(2) Potassium Iodide.
(3) Soluble Starch.
(4) Atomizer.

The chemicals should be purchased chemically pure and half pound each should be enough for any plant at one time. DeVilbiss Atomizer No. 30 is very satisfactory.

For stock solutions of the three chemicals make 200 cc. each to be kept separately until used:

(1) 1 per cent Potassium Ferricyanide (2 gm. dissolved in 200 cc. water).
(2) 1 per cent Potassium Iodide (2 gm. dissolved in 200 cc. water).
(3) 5 per cent Soluble Starch (10 gm. dissolved in 200 cc. water).

Mix the weighed starch with a little of the measured cold water and then pour into the remaining water boiling hot and continue to boil until the starch is in solution. Starch solution will not keep for many days and must not be used when it begins to sour.

To make a test for zinc chloride penetration, simply pour 10 cc. each (or equal amounts) of the three stock solutions into atomizer and spray the cross-section of the tie evenly all over, if zinc chloride is present a deep blue stain will result showing clearly the depth of penetration.

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*The standard silver nitrate solution should be made and standardized only by a trained chemist; if the services of such a chemist are not available, the standard solution should be obtained from a reliable chemical supply firm.

[16] Adopted, Vol. 21, 1920, pp. 358, 1387; Vol. 27, 1926, pp. 959, 1414.

[17]DETERMINATION OF ZINC IN TREATED TIMBERS

NOTE—*It is suggested that this method be applied by a Chemist.*

Taking Samples

The tools necessary for taking samples are a cross-cut saw and a one-inch auger. These should be wiped perfectly clean each time before taking a sample, in order to avoid contaminating the samples.

The timbers from which samples are to be taken for analysis should be selected before the charge is loaded, and carefully weighed individually. They should be of average size and comparatively free from knots. After treatment they should be weighed and then piled until the dripping has stopped, when the samples may be taken.

For ordinary determinations, timbers such as ties should be sawed at two points, viz., two feet from the end and at the center of the tie. These sections should be designated Section No. 1 and Section No. 2, respectively. In special cases where it may be necessary to cut a tie into several sections, the exact distance from the end of each section should be given.

When a large number of ties are to be analyzed, it will be sufficient to cut but one section two feet from the end, thereby saving the six-foot piece for a narrow-gage tie.

After the sections have been cut, three samples should be taken from each section, as follows: No. 1, one-half inch from outside; No. 3, at the center of the section; No. 2, half-way between No. 1 and No. 3. The samples are taken by boring a hole 2 inches deep with a one-inch bit, saving all the borings. Each sample should be properly labeled, as Tie No. —, Section No. —, Sample No. —, and a list made showing the location, date, number of run, kind of treatment and weight of each tie before and after treatment.

Method of Determining Zinc Chloride in Samples

Three grammes of dry borings should be weighed into a 250 cc. flask and three cc. concentrated sulphuric acid added. The flask should be gently heated on a sand bath or hot plate until the wood becomes thoroughly charred. A few drops of concentrated nitric acid should then be added. When the brown fumes have disappeared, a few more drops should be added, and the addition continued, a few drops at a time (toward the last the amount should be increased), until the organic matter is all destroyed. When this point is reached, the liquid will remain colorless on further heating. The flask should then be allowed to cool and diluted with 100 cc. of water (the water should be added carefully at first). As a rule, the residue in the flask will be completely dissolved, but if there should be a slight sediment, it may be disregarded. Ammonium hydroxide should be added until distinctly alkaline, and allowed to cool. If there is a precipitate of iron hydroxide, or if there has been any undissolved sediment in the flask, it should be filtered; if not, it should be poured into a 400 cc. beaker and 5 cc. ammonium sulphide added and allowed to stand over night. It should then be filtered into an 11 cm. filter paper, washing thoroughly with water containing ammonium sulphide, and dried. It should then be incinerated in a porcelain crucible and roasted until the zinc chloride is converted to zinc oxide. The weight should be divided by three and the result multiplied by 1.674, which will give the number of grammes of zinc chloride contained in one gramme of the wood examined, or the number of pounds per pound. To convert this result into pounds of zinc chloride per cubic foot of wood, multiply by the weight in pounds of one cubic foot of the wood.

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[17] Adopted, Vol. 9, 1908, pp. 712-714, 768; Vol. 11, Part 2, 1911, pp. 746, 747, 860; Vol. 27, 1926, pp. 960, 1414.

[18]FORMS FOR REPORTING INSPECTION

Two forms for reporting inspection of treatment are shown. Form "A" provides a record of the treatment and the determinination of the absoprtion of the preservative by gage readings. Form "B" provides a record of the determination of the absorption by weighing.

These forms are intended as general guides for reporting and keeping records of the inspection of the treatment of timbers, and may be varied to suit any special kind of treatment.

The following is explanatory of the gage readings, designed by letter on Form "A":

Reading "A"—Is the reading of the measuring tank gage before the preservative is put into the cylinder.

Reading "B"—Is the tank gage reading when the cylinder is completely filled.

Reading "C"—Is the tank gage reading when the pumping of the liquid into the cylinder is stopped.

Reading "D"—Is the tank gage reading after all the liquid from the charge is returned to the measuring tank.

Reading "A" minus "D," corrected for temperatures, gives the number of gallons used in the charge.

Reading "B" minus "C" gives the number of gallons pumped into the timber after the cylinder is filled and is used to give the gross absorption for processes where oil is taken out of the timber by an initial air pressure, or by a final vacuum, or both. There will be a discrepancy in this gross absorption, due to the amount of oil absorbed by the timber while cylinder is being filled.

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[18] Adopted, Vol. 14, 1913, pp. 713-716, 1165, 1166; Vol. 27, 1926, pp. 961, 1414.

Form A. **M. W. 1700**

____
(Name of Railroad)

________________________ Department

________________________ Plant

________________________ Inspector

Date															
Kind of Treatment															
Retort Number															
Charge Number															
Liquid Used															
Percent of Chloride															
Steam or Air Admitted															
Vacuum Applied															
Liquid Admitted															
Pump Started															
Treatment Ended															
Steam or Air Pressure, Lbs.															
Vacuum, Inches															
Pressure of Liquid, Lbs.															
Measuring Tank Number															
Gallons per Tank Foot															
Reading A.															
Temperature A. Degrees Fahrenheit															
Reading B.															
Temperature B. Degrees Fahrenheit															
Reading C															
Temperature C. Degrees Fahrenheit															
Reading D.															
Temperature D. Degrees Fahrenheit															
Gals Pumped Into Timber per Charge B. minus C.															
Gallons Pumped Into Timber per Tie															
Pounds Pumped Into Timber per Cu. Ft.															
Total Gallons Used 100° Fahrenheit A. minus D.															
Gals per Cu. Ft. of Timber															
Gallons per Tie															
Lbs. per Cu. Ft. of Timber															
Lbs. of Chloride per Cu. Ft. Timber															
Material Treated.															

Form B.

M. W. 1701

Date ______ ______ (Name of Railroad) ______ Date ______

Kind of Treatment ______ ______ Plant ______ Kind of Treatment ______

Run No. ______ Kind of Timber ______ Kind of Timber ______ Run No. ______

Tram Number	No. of Ties	Gross Weight Before Treatment	Weight of Tram	Weight of Ties Before Treatment	Gross Weight After Treatment	Weight of Ties After Treatment	Gain Per Tie	Tram Number	No. of Ties	Gross Weight Before Treatment	Weight of Tram	Weight of Ties Before Treatment	Gross Weight After Treatment	Weight of Ties After Treatment	Gain Per Tie

______ Inspector

Lbs. of Oil Per Tie ______ % of Chloride in Solution ______

Total Gals. Oil @ 100° Fahr. ______ Total Lbs. Liquid Used ______

Gals. Absorbed per Tie ______ Lbs. Chloride per Tie ______

______ Inspector

Lbs. of Oil Per Tie ______ % of Chloride in Solution ______

Total Gals. Oil @ 100° Fahr. ______ Total Lbs. Liquid Used ______

Gals. Absorbed per Tie ______ Lbs. Chloride per Tie ______

[19]SPECIFICATIONS FOR PRESERVATIVE TREATMENT OF DOUGLAS FIR

(I) INTRODUCTION

1. The physical structure of Douglas Fir causes it to be refractory to preservative treatment, this quality varying with the conditions under which the timber is grown. The heartwood offers great resistance to the injection of preservative; the sapwood can be treated more readily, but since the natural timber contains only a thin shell of sapwood, the general treatment is difficult. Furthermore, since sawed timber may be entirely heartwood, or may contain only a very small amount of sapwood, it follows that this type of material is more difficult to treat than piling, which contains the full amount of original sapwood.

Perforating or Incising

2. The refractory quality of Douglas Fir has led to the development of the principle of perforating or incising the timber mechanically as an aid to injection of preservatives. The advantages of this procedure have been conclusively demonstrated. Thus far the practice has been confined to tie and pole material. The incisions are so made and spaced that the preservative entering the wood unites between adjacent incisions and produces a more uniform and deeper penetration than would otherwise be possible.

Piling Sapwood

3. In order to obtain an adequate treatment, all piling material should have a minimum sapwood thickness equal to the depth of penetration desired. (See General Specification Requirements, Section 8, Penetration.)

Seasoning Before Treatment

4. In accordance with the general recommendations of this Association for all timber, Douglas Fir should be air-seasoned before treatment wherever possible. If this is done, artificial seasoning is avoided, the treating cycle is materially shortened, and a better treatment is secured. The proper amount of such seasoning will vary with climatic conditions and must be determined for each locality by actual tests.

Material stored for seasoning should be piled in accordance with the recommended practice of this Association.

Artificial Seasoning

5. If air-seasoning cannot be secured, the material must be artificially seasoned in order to accomplish treatment. The method of such seasoning will depend upon the kind of treatment. In cases where artificial seasoning is to be secured by boiling the material in the preservative oil, it is important that the specified allowable temperatures be not exceeded, to avoid injury of the timber. In treatments where zinc chloride is used, the only method of artificial seasoning is that of steaming, and this procedure is not recommended by the Association.

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[19] Adopted, Vol. 27, 1926, pp. 965, 1416.

Machining, Cutting, Framing

6. With the exception noted below for processes in which zinc chloride is used as a preservative, all machining, cutting or framing of timber to be treated should be accomplished before treatment as far as practicable, to minimize subsequent cutting through the treated shell and exposure of untreated wood.

Preservatives

7. The following preservatives are commonly used for the treatment of Douglas Fir:

Creosote.
Creosote-Petroleum Mixture.
Creosote Coal-Tar Solution.
Creosote-Zinc Chloride Emulsion.
Zinc Chloride.

Preservative Treatments

8. Douglas Fir is commonly treated by the following preservative processes:

Full Cell Process.
Lowry Process (Empty Cell Process with Final Vacuum).
Rueping Process (Empty Cell Process with Initial Air and Final Vacuum).
Card Process (Creosote-Zinc Chloride Emulsion Process).
Zinc Chloride Process.

The selection of treatment is largely determined by the intended use of the treated material. All the above preservatives and treatments have been applied to timber for general inland purposes. Use of timber treated by the Zinc Chloride Process is limited by conditions of humidity. The Full Cell Process with straight creosote as the preservative is the only treatment recommended by the Association for the preservation of piling, and the timber to be used in sea water exposed to the action of marine borers.

Final Retention of Preservatives

9. The amount of preservative to be retained by the timber is optional with the Railroad, within the limitations of the various processes and necessary minimums specified by the Association. The amount required will depend largely upon the intended use of the treated material. The following amounts are recommended:

FOR DOUGLAS FIR TIES AND STRUCTURAL TIMBER

(For ties and moderate size structural timbers having dimensions over 6 inches and under 12 inches. A greater amount of preservative should be injected for timbers having dimensions less than 6 inches; a smaller amount can be injected for timbers in which the smaller dimension is more than 12 inches.)

(a) Treatment by Full Cell Process with Creosote, Creosote-Petroleum Mixture or Creosote Coal-Tar Solution—not less than 10 lb. of preservative per cu. ft. of timber.

(This amount is necessary to secure a minimum adequate penetration. A treatment of 10 lb. by the Full Cell Process will give about the same penetration as a 6 lb. treatment by the Empty Cell Process.)

(b) Treatment by Empty Cell Process with Creosote, Creosote-Petroleum Mixture or Creosote Coal-Tar Solution—6 to 8 lb. of preservative per cu. ft. of timber.

(c) Treatment by Creosote-Zinc Chloride Emulsion Process—3 lb. creosote and 0.4 to 0.5 lb. dry zinc chloride per cu. ft. timber.

(d) Treatment by Zinc Chloride Process—0.5 lb. dry zinc chloride per cu. ft. timber.

FOR DOUGLAS FIR PILING NOT USED IN SEA WATER

Treatment with Creosote—not less than 10 lb. creosote per cu. ft. timber.

FOR DOUGLAS FIR STRUCTURAL TIMBER AND PILING USED IN SEA WATER

Treatment by Full Cell Process with Straight Creosote—not less than 12 lb. creosote per cu. ft. timber.

Seasoning After Treatment

10. To secure the maximum benefits of the preservative process it should not be used immediately after being treated. Tie material should be seasoned a minimum of 60 days after treatment.

(II) GENERAL SPECIFICATION REQUIREMENTS FOR DOUGLAS FIR

(For All Methods of Treatment)

Quality of Timber

1. The timber shall conform to the specifications of this Association.

Physical Condition—Machining, Cutting, Framing, Trimming

2. For Ties.—All machining, such as boring for spikes and adzing, shall be done before treatment. Ties shall be bored, adzed, incised and branded as specified by the Railroad.

For Structural Timber.—All boring (see exception for processes using zinc chloride in Introduction, Section 6), cutting and framing shall be accomplished, so far as practicable, before treatment, and as specified by the Railroad.

For Piling.—All piling shall have bark and inner skin removed, knots cut flush and butts and tips trimmed squarely. Piling previously stored in sea water shall have barnacles and similar forms of sea life removed. Piling showing attack of insects or marine borers shall be rejected.

Seasoning Before Treatment

3. Timber shall be air-seasoned or artificially seasoned before injection of the preservative under pressure, as desired by the Railroad. Such seasoning shall be accomplished in accordance with the specifications of this Association.

Moisture Content

4. Timber shall be considered thoroughly seasoned when its moisture content is 20 per cent or less of its oven-dry weight.

All material treated in any one charge shall have approximately the same moisture content.

Preservative

5. The preservative desired by the Railroad shall conform to the specifications of this Association.

Preservative Treatment

6. The preservative treatment desired by the Railroad shall conform to the specifications of this Association. (See Specifications for Preservative Treatments.)

Final Retention of Preservative

7. The amount of preservative to be retained by the timber shall be specified by the Railroad.

Piling not used in sea water shall have a minimum final retention of 10 lb. of creosote per cubic foot of timber. Structural timber and piling used in sea water and subject to the action of marine borers (treated by the Full Cell Process with creosote) shall have a minimum final retention of 12 lb. of creosote per cubic foot of timber.

The quantity of creosote oil retained shall be calculated on the basis of 100 degrees Fahr. from reading of working tank gages and scales or from weights of at least one-tenth of the material on a suitable track scale before and after treatment, checked as may be desired by the Railroad's representative.

Penetration

8. The penetration of preservative shall be as specified by the Railroad.

For piling the penetration shall correspond to the specified final retention of preservative, as follows:

MINIMUM SAPWOOD AND PENETRATION FOR PILING

(Treated by Full Cell Process with Straight Creosote)

Amount of preservative to be retained	*Minimum sapwood and penetration*
10 lb. creosote per cu. ft.	½ inch
12 lb. creosote per cu. ft.	¾ inch
14 lb. creosote per cu. ft.	1 inch
16 lb. creosote per cu. ft.	1¼ inch

In order to determine the penetration of the oil, borings should be made with an increment borer in at least six pieces in each cylinder load. The holes should be plugged with creosoted plugs at least one-sixteenth inch larger than the diameter of the hole.

General Conditions

9. All holes bored for test purposes shall be plugged with treated plugs furnished by the Treating Company.

All timber must be handled with care, particularly after treatment, to avoid damaging the edges or breaking through the treated shell and exposing the untreated wood. Sharp pointed tools, such as cant hooks, peavies, pickaroons and crowbars, must only be used in the ends of timbers. Injured material shall be rejected.

The Treating Company shall maintain the necessary thermometers and gages to indicate and record accurately the conditions at all stages of treatment, and all equipment shall be maintained in a condition satisfactory to the Railroad.

The Treating Company shall permit the Railroad inspectors or representatives to make all necessary tests of materials and equipment pertaining to work covered by these specifications, and shall co-operate in making such tests.

The Treating Company shall provide for the use of the Railroad inspectors or representatives all necessary chemicals and facilities for making tests required by these specifications.

The Railroad inspectors or representatives shall have access to all parts of the treating plant and to all records pertaining to work covered by these specifications.

(III) PRESERVATIVE TREATMENTS FOR DOUGLAS FIR

(To be inserted in General Specification Requirements)

Full Cell Process

(For use with Straight Creosote, Creosote-Petroleum Mixture or Creosote Coal-Tar Solution)

FOR TIES AND STRUCTURAL TIMBER

Artificial Seasoning

1. When the timber has not been air-seasoned, it may be artificially seasoned in the treating cylinder by boiling in the preservative oil under a vacuum at temperatures ranging from 180 degrees Fahr. to 200 degrees Fahr., as follows:

After the timber is placed in the treating cylinder, preservative heated to not less than 170 degrees Fahr. shall be admitted until the timber is completely immersed. The connections between the condenser and vapor drum on the treating cylinder shall then be opened and steam admitted through the heating coils and so regulated that the temperature in the treating cylinder is caused to rise as fast as the condensation will permit, until a temperature of not exceeding 200 degrees Fahr. is reached. At the beginning of the boiling period, in order to eliminate the possibility of the oil surging and entering the vapor lines and condenser, the vacuum produced should not exceed 15 inches. After the temperature has been raised not exceeding 200 degrees Fahr., the vacuum shall be increased to at least 20 inches and so maintained until the condensation passing off from the timber and collecting in the hot well of the condenser does not exceed 0.1 of a lb. per cubic foot of timber per hour.

Preparatory Bath

2. In the case of thoroughly air-seasoned timber, it is not necessary to boil under a vacuum, but because of the refractory nature of Douglas Fir, it must be held in a hot oil bath at temperatures from 180 degrees to 190 degrees Fahr. for a period of 6 to 8 hours, in order to obtain the necessary absorption without running into extremely high pressures.

Treating Operation

3. At the completion of the seasoning or bath periods, the treating cylinder shall be completely filled with preservative heated to not less than 170 degrees nor more than 190 degrees Fahr. The pressure in the cylinder shall then be gradually raised over a period not less than 1 hour and 30 minutes to pressure not less than 125 nor more than 175 pounds per square inch depending upon the dimension of the material. This operation shall be continued until the timber has absorbed sufficient preservative to insure the specified final retention.

The temperature of the preservative during the pressure period shall be not less than 170 degrees Fahr. nor more than 200 degrees Fahr. After the proper injection of preservative has been secured, the cylinder shall be speedily emptied of preservative, and a vacuum of 22 inches or more promptly created and maintained for a period not more than 1 hour nor less than 2 hours, so that the timber can be removed from the cylinder free of dripping preservative.

Final Retention of Preservative

(See General Specification Requirements, Section 7.)

4. The amount of preservative finally retained by the timber shall be determined from readings of working tank gages or scales, or by weighing sufficient representative timber, before and after treatment, with proper correction for loss in moisture content.

Penetration

(See General Specification Requirements, Section 8.)

5. Representative timber from each charge shall be tested for penetration. In determining penetration, light discoloration of the wood from treatment shall not be considered.

FOR PILING

Specifications for treatment of piling by the Full Cell Process are the same as given above for ties and structural timber with the exception that temperatures up to 220 degrees Fahr. will be permitted.

RUEPING PROCESS

(For use with Creosote, Creosote-Petroleum Mixture or
Creosote Coal-Tar Solution)

Artificial Seasoning

1. When the timber has not been air-seasoned, it may be artificially seasoned in the treating cylinder by boiling in the preservative oil under a vacuum at temperatures ranging from 180 degrees Fahr. to 200 degrees Fahr. as follows:

After the timber is placed in the treating cylinder, preservative heated to not less than 170 degrees Fahr. nor more than 200 degrees Fahr. shall be admitted until the timber is completely immersed. The connections between the condenser and vapor drum on the treating cylinder shall then be opened and steam admitted through the heating coils and so regulated that the temperature in the treating cylinder is caused to rise as fast as the condensation will permit, until a temperature of about 190 degrees Fahr. is reached. At the beginning of the boiling period, in order to eliminate the possibility of the oil surging and entering the vapor lines and condenser, the vacuum produced should not exceed 15 inches. After the temperature has been raised to 190 degrees Fahr. the vacuum shall be increased to 20 inches and so maintained until the condensation passing off from the timber and collecting in the hot well of the condenser does not exceed 0.1 of a lb. per cubic foot of timber per hour.

Preparatory Bath

2. In the case of thoroughly air-seasoned timber, it is not necessary to boil under a vacuum, but becauce of the refractory nature of Douglas Fir, it may be held in a hot oil bath at temperatures from 180 degrees to 190 degrees Fahr. for a period of 6 to 8 hours, in order to obtain the necessary absorption without running into extremely high pressures.

After completion of the seasoning or bath periods, the preservative shall be immediately drained completely from the treating cylinder. If a vacuum has been used, the cylinder shall be drained immediately upon breaking the vacuum.

Treating Operation

3. As soon as the treating cylinder has been completely drained, the timber shall be subjected to an air pressure of sufficient intensity and duration to provide for the specified final retention. The preservative shall then be introduced, the air pressure being maintained constant until the cylinder is filled. The pressure of the preservative shall then be gradually raised until it is not less than 100 lb. per square inch greater than the air pressure at which the treating cylinder was refilled. This pressure shall be held until sufficient preservative has been introduced to give the specified final retention.

Pressures in excess of 200 lb. per square inch will not be permitted. The temperature of the preservative during the pressure period shall be not less than 170 degrees Fahr. nor more than 200 degrees Fahr. Upon completion of the pressure period, the treating cylinder shall be speedily emptied of preservative and a vacuum of not less than 22 inches promptly created and maintained for a period not to exceed one hour nor more than two hours, so that the timber can be removed from the treating cylinder free of dripping preservative.

Final Retention of Preservative

(See General Specification Requirements, Section 7.)

4. The amount of preservatives finally retained by the timber shall be determined from readings of working tank gages or scales, or by weighing sufficient representative timber, before and after treatment, with proper correction for loss in moisture content.

Penetration

(See General Specification Requirements, Section 8.)

5. Representative timber from each charge shall be tested for penetration. In determining penetration, light discoloration of the wood from treatment shall not be considered.

LOWRY PROCESS

(For use with Creosote, Creosote-Petroleum Mixture or Creosote Coal-Tar Solution)

Treatment of Douglas Fir by the Lowry Process is substantially the same as that of the Rueping Process with the exception that initial air pressure is omitted.

CREOSOTE-ZINC CHLORIDE EMULSION PROCESS

1. Except when ordered otherwise by the Railroad, the timber to be treated shall be air-seasoned until the moisture in it will not prevent injection of the specified amount of preservative.

Treating Operation

2. The timber shall be steamed in the treating cylinder for at least one hour at a pressure not less than 15 nor more than 20 lb. per square inch. After releasing the steam pressure and condensation, a vacuum of at least 22 inches shall be created.

Without breaking the vacuum, the preservative shall be introduced until the cylinder is completely filled. The pressure shall then be gradually raised over a period not less than 1 hour and 30 minutes to a pressure not less than 125 nor more than 175 lb. per square inch. This pressure shall be maintained until the required absorption has been obtained.

The temperature of the preservative before introduction and during the entire pressure period shall be not less than 170 degrees Fahr. nor more than 200 degrees Fahr. During the entire pressure period the preservative solution shall be agitated mechanically to keep it in emulsion.

After the injection of preservative is completed, the cylinder shall be emptied of preservative and a vacuum of 22 inches or more maintained until the timber can be removed from the cylinder free of dripping preservative.

Final Retention of Preservative

(See General Specification Requirements, Section 7.)

3. The amount of solution finally retained by the timber shall be determined from readings of working tank gages or scales, or by weighing sufficient representative timber before and after treatment.

Penetration

(See General Specification Requirements, Section 8.)

4. At least once each day the Railroad's representative shall determine penetration by analysis. The "Iodine-Potassium Ferricyanide Starch" color reaction test to determine the penetration by its visibility will generally be satisfactory.

ZINC CHLORIDE PROCESS

Seasoning Before Treatment

1. Except when ordered otherwise by the Railroad, the timber to be treated shall be air-seasoned until the moisture in it will not prevent injection of the specified amount of preservative.

Preservative Solution

2. The preservative solution shall be no stronger than necessary to obtain the required retention of preservative with the largest volumetric absorption that is practicable, and shall be thoroughly mixed before use. Its strength shall not exceed 5 per cent and shall be determined by analysis. Chemical titration, using a silver nitrate solution with potassium chromate indicator, will usually be satisfactory.

Treating Operation

3. Air-seasoned material shall be steamed in the treating cylinder for not less than 1 hour nor more than 2 hours, at a pressure of not more than 20 lb. per square inch, the cylinder being provided with vents to relieve it of stagnant air and insure proper circulation of the steam, and being drained to prevent condensate from accumulating in sufficient quantity to reach the timber. After steaming is completed, a vacuum of at least 22 inches shall be created and maintained until the timber is as dry and as free from air as practicable.

Before the preservative is introduced, the cylinder shall be drained of condensate, and if the vacuum is broken, a second one as high as the first shall be created. The preservative shall be introduced without breaking the vacuum until the cylinder is filled. The pressure shall be gradually raised and maintained at not less than 125 lb. per square inch or more than 175 lb. maximum until the required quantity of preservative is injected into the timber, or until less than 5 per cent of the total quantity required has been injected during the latter half of 1 hour, throughout which the rate of injection has persistently decreased while the pressure has been held continuously at 165 or more lb. per square inch.

The temperature of the preservative during the pressure period shall be not less than 150 degrees Fahr. nor more than 190 degrees Fahr. and with an average of at least 170 degrees Fahr. After the cylinder is emptied of the preservative solution, a vacuum shall be created and maintained until the timber can be removed from the cylinder free of dripping preservative.

Final Retention of Preservative

(See General Specification Requirements, Section 7.)

4. The amount of solution finally retained by the timber shall be determined from readings of working tank gages or scales, or by weighing sufficient representative timber before and after treatment.

Penetration

(See General Specification Requirements, Section 8.)

5. At least once each day the Railroad's representative shall determine penetration by analysis. The "Iodine-Potassium Ferricyanide Starch" color reaction test to determine the penetration by its visibility will generally be satisfactory.

COMMITTEE XVIII

ELECTRICITY

Explanatory Note.—The recommendations of the Committee on Electricity will hereafter appear in the "Manual of the Electrical Section," American Railway Association.

The following references give volume and page of the Proceedings of the American Railway Engineering Association where the material may be found.

(A) Recommended Practice Relating to a Railway Individually

Definitions

Adopted, Vol. 12, part 1, 1911, pp. 152, 222; Vol. 13, 1912, pp. 510, 998; Vol. 20, 1919, pp. 194, 854; Vol. 22, 1921, pp. 140, 969.

Overhead Clearance Lines for Permanent Way Structures on Electrified Railways

Adopted, Vol. 15, 1914, pp. 618, 624, 1071.

Clearance Lines for Equipment and Permanent Way Structures Adjacent to Third Rail and for Third Rail Structures

Adopted, Vol. 13, 1912, pp. 511, 525, 998; Vol. 16, 1915, pp. 927, 1187.

Specifications for the Construction of Overhead Electric Supply Lines for Railroad Use on Railroad Property

Adopted, Vol. 25, 1924, pp. 310, 1266; Vol. 26, 1925, pp. 261, 1307.

Specifications for the Maintenance of Overhead Electric Supply Lines

Adopted, Vol. 26, 1925, pp. 261, 1307; Vol. 27, 1926, pp. 138, 1288.

Specifications for the Joint Use of Poles for Power, Communication and Signal Circuits

Adopted, Vol. 27, 1926, pp. 131, 1291.

Specifications for Underground Conduit Construction for Power Cables

Adopted, Vol. 22, 1921, pp. 140, 970.

Electrolysis—Report of American Committee

(Vol. 18, Proceedings 1917, pp. 171, 1444—Bulletin 244, Feb. 1922.)

(B) Recommended Practice Dealing with Relationship Between Railways and Industries or Individuals Which They Serve

Rules for Recommended Practice Relative to the Protection of Oil Sidings from Danger Due to Stray Currents

Adopted, Vol. 24, 1923, pp. 602, 1192.

(C) Recommended Practice Relating to Manufacture and Purchase of Railway Appliances and Materials

Specifications for Electric Wires and Cables
Adopted, Vol. 22, 1921, pp. 147, 969.

Incandescent Lamp Schedule
Adopted, Vol. 30, 1929, pp. 448, 1442.

Specifications for Friction Type
Adopted, Vol. 27, 1926, pp. 138, 1291.

Specifications for Porcelain Insulators for Railroad Supply Lines
Adopted, Vol. 27, 1926, pp. 142, 1292.

Specifications for Rubber Insulating Tape
Adopted, Vol. 28, 1927, pp. 121, 1244.

Specifications for Adhesive Tape for General Use for Electrical Purposes
Adopted, Vol. 24, 1923, pp. 595, 1192.

(D) Recommended Practice Defining Relationship Between the Railroad and Its Contractors, or Public Service Corporation

Specifications for Electric Light, Power Supply and Trolley Lines Crossing Railways
Adopted, Vol. 21, 1920, pp. 208, 1378; Vol. 24, 1923, pp. 609, 1192.

COMMITTEE XIX

CONSERVATION OF NATURAL RESOURCES

[1]RULES FOR THE PREVENTION OF THE SPREAD OF FOREST AND FIELD FIRES

Precautionary Measures

(1) Railways shall not permit fires, burning waste, live coals, ashes, wood or other substances in a burning state to be deposited on tracks or right-of-way, unless such fires are completely extinguished immediately thereafter; except where such fires are deposited in pits provided for that purpose, or deposited on parts of track specially designated as being safe for such purpose.

(2) Railways shall take the necessary measures to maintain tracks and right-of-way in safe condition to prevent the spread of forest, prairie and field fires.

Preventive measures shall be taken in all cases where coal- or wood-burning locomotives are operated through districts where there is possibility of fire running. In general, such measures shall be as follows:

Disposal of Inflammable Material

(a) All inflammable material, such as standing dead trees, logs, dead or decayed wood, brush, dry leaves and dry grass, within the limits of the right-of-way, shall be burned off early in the spring months, and as often thereafter as may be deemed necessary.

Supervision of Burning Operations

(3) No railway, through its agents, employees, or contractors, shall burn, or cause to be burned, any cross- or switch-ties, mowings, débris, or other litter on or near the right-of-way except under proper supervision, to prevent such fires from spreading beyond control. During the period of greatest fire danger, no such burning shall be done by the railway forces.

Reporting Fires

(4) Railways shall instruct and require stationmen and other employees, agents, or contractors, to report fires and extinguish same when on or adjacent to the right-of-way, as follows:

(a) Enginemen, conductors, or trainmen, who discover or receive notice of a fire burning upon or adjacent to the right-of-way, or of a fire which threatens land or property located adjacent to the right-of-way shall report its existence and exact location by milepost to the agent or person in charge at the nearest point where communication by telegraph or telephone is available, and also notify the first section employees passed. Notice of such fire shall also be given immediately by enginemen by a system of warning whistles.

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[1] Adopted, Vol. 21, 1920, pp. 292, 1381.

(b) The agent or other employee of the railway shall at once notify the nearest section employees, and, if possible, the nearest Federal or State Forest Fire official, of the existence and exact location by milepost of such fire.

(c) When a fire is reported or discovered burning adjacent to the right-of-way of a railway, regardless of its origin, such sectionmen or other employees of the railway as are available, shall at once proceed to the location of the fire and extinguish it, provided such sectionmen or other employees at the time are not engaged in work essential to the safe operation of trains.

(d) Railways operating through forest districts shall provide suitable blank forms for reporting fires occurring on or adjacent to the railway right-of-way, regardless of their origin. Section foremen shall be instructed and required to make detailed written report on the prescribed form of any fire, however trivial, and to forward such reports promptly to their superior. The intent of this rule is to determine and, if possible, to eliminate the causes of fire.

Special Instructions

(5) Railways shall issue special instructions to employees concerning the foregoing rules or regulations. Such rules or regulations shall be posted on bulletin boards at engine houses, section houses, stations, and in conspicuous places on other parts of the right-of-way of the railway.

Co-operation with Other Agencies

6. In view of the aid that may be rendered by the various State Forest Fire Protective organizations, the officers of the Forest Service of the United States Department of Agriculture, and Timber Owners' Protective organizations, the closest possible co-operation by railways with such agencies, wherever they exist, is desired and encouraged. The details of such co-operation between the railway forces and the protective organizations is to be arrived at by mutual agreement between the parties concerned.

Minimum Requirements

(7) The foregoing rules or regulations constitute minimum requirements. It is not intended that they shall supersede state laws or regulations where additional measures are in effect, but they are supplementary thereto.

COMMITTEE XX

UNIFORM GENERAL CONTRACT FORMS

[1]FORM OF PROPOSAL

.........................., 19...

.... the undersigned propose to furnish all the materials, superintendence, labor, equipment and transportation, except as otherwise specified, and to execute, construct and finish in an expenditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer ....

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and agree to commence the work within .... days after receipt of the notice of award of the contract, and to complete the work within .... days thereafter, in accordance with the terms, conditions, requirements and specifications covered by the request for proposals made by .... dated .... for the following prices:

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(Signed) ....

[2]FORM OF CONSTRUCTION CONTRACT

THIS CONTRACT, made this ...... day of .... in the year ...., by and between ....

....

....

hereinafter called the Contractor, and ....

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....

hereinafter called the Company:

WITNESSETH: That, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto, and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

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[1] Adopted, Vol. 15, 1914, pp. 921, 1155.
[2] Adopted, Vol. 28, 1927, pp. 439, 1434.

The Contractor shall furnish all of the materials, superintendence, labor, tools, equipment and transportation, except as hereinafter specified, and shall execute, construct and finish, in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Company, all of the work required for ....

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in accordance with the plans identified by the signatures of the Contractor, and the Chief Engineer, dated ...., 19...., and described ....

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and the Specifications hereto attached, all of which are made a part of this contract.

The work covered by this contract shall be commenced on or before the .... day of ...., 19......, and shall be completed on or before the .... day of .... 19....

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And, whereas, TIME being of the essence of this contract and it is agreed that the Company would suffer loss by the failure of the Contractor to have said work completed in all its parts on said day, and as it might be difficult and expensive to accurately compute the amount of such loss; in order to avoid such expense and difficulty, the Contractor hereby expressly covenants and agrees to pay the Company the sum of .... dollars per day for each and every day, Sundays and legal holidays only excepted, after said .... day of .... during or upon which the said work or any part thereof remains incomplete and unfinished, not as a penalty, but as the liquidated actual losses which the Company will suffer on account of any failure on the part of the Contractor to have the said work completed in all its parts on said day; and that any sum which may be due the Company for such losses may be deducted and retained by the Company from any balance which may be due the Contractor when the said work shall have been finished and accepted as hereinafter provided. It is, however, agreed that in case any failure to complete the said work or some part thereof on said day shall be due to any cause beyond the Contractor's control and for which the Chief Engineer has granted an extension of time, such delays form no part of the number of days for each and every one of which the Contractor is to pay the said Company the sum of .... dollars, as herein specified.

And in consideration of the completion of the work described herein, and the fulfillment of all stipulations of this contract to the satisfaction and acceptance of the Chief Engineer of the Company, the Company shall pay, or cause to be paid, to the Contractor, the amount due to the Contractor, based on the following prices:

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1. Intent of Plans and Specifications

All work that may be called for in the specifications and not shown on the plans, or shown on the plans and not called for in the specifications, shall be executed and furnished by the Contractor as if described in both these ways; and should any work or material be required which is not detailed in the specifications or plans, either directly or indirectly but which is nevertheless necessary for the proper carrying out of the intent thereof, the Contractor is to understand the same to be implied and required, and shall perform all such work and furnish any such material as fully as if they were particularly delineated or described.

2. Contractor's Understanding

It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all other matters which can in any way affect the work under this contract. No verbal agreement or conversation with any officer, agent or employee of the Company, either before or after the execution of this contract, shall affect or modify any of the terms or obligations herein contained.

3. Land of Company, Use of, by Contractor

The Company shall provide the land upon which the work under this contract is to be done, and will, so far as it can conveniently do so, permit the Contractor to use so much of its land as is required for the erection of temporary construction facilities and storage of materials, together with the right of access to same, but beyond this, the Contractor shall provide, at his cost and expense, any additional land required.

4. Consent to Transfer

The Contractor shall not let or transfer this contract or any part thereof (except for the furnishing and delivery of material) without consent of the Chief Engineer, given in writing. Such consent does not release or relieve the Contractor from any of his obligations and liabilities under the contract.

5. Risk

The work under this contract in every respect shall be at the risk of the Contractor until finished and accepted, except damage or injury caused directly by Company's agents or employees.

6. Engineer and Chief Engineer

Wherever in this contract the word Engineer is used, it shall be understood as referring to the Chief Engineer of the Company, acting personally or through an assistant duly authorized in writing for such act by the Chief Engineer, and wherever the words Chief Engineer are used it shall be understood as referring to the Chief Engineer in person, and not to any assistant engineer.

7. Power of Engineer

The Engineer shall have power to reject or condemn all work or material which does not conform to this contract; to direct the application of forces to any portion of the work which, in his judgment, requires it; to order the force increased or diminished, and to decide questions which arise between the parties relative to the execution of the work.

8. Waiver

It is expressly understood and agreed that any waiver on the part of the Company or the Engineer, of any term, provision or covenant of this contract, shall not constitute a precedent, nor bind the Company or the Engineer, to a waiver of any succeeding breach of the same or any other of the terms, provisions or covenants of this contract.

9. Adjustment of Dispute

All questions or controversies which may arise between the Contractor and the Company, under or in reference to this contract, shall be subject to the decision of the Chief Engineer, and his decision shall be final and conclusive upon both parties.

10. Bond

The Contractor unless notified to the contrary, shall, at the time of the execution and delivery of this contract, and before the taking effect of the same in other respects, furnish and deliver to the Company a written bond of indemnity to the amount of .... Dollars, ($..........) in form and substance and with surety thereon satisfactory and acceptable to the Company, to insure the faithful performance by the Contractor of all the covenants and agreements on the part of the Contractor contained in this contract.

This bond shall remain in force and effect for the full amount or such smaller sum as may at any time be specified by the Chief Engineer.

11. Permits

Permits of a temporary nature necessary for the prosecution of the work shall be secured and paid for by the Contractor. Permits for permanent structures or permanent changes in existing facilities shall be secured and paid for by the Company.

12. Fire Insurance

The Contractor shall secure in the name of the Company, policies of fire insurance in amount, form and companies, satisfactory to the Chief Engineer, upon such structures and material as shall be specified by the latter, payable to the Company for the benefit of the Contractor or the Company, as the Chief Engineer shall find their interests to appear.

13. Workmen's Compensation Insurance

The Contractor shall comply with all the laws of the State where the contract is to be performed, arising under any "Workmen's Compensation Act," and shall at all times carry and pay the premiums on all policies of insurance required by the laws of the State where the work is being performed, under any "Workmen's Compensation Act," so that the Company shall be fully protected from any and all claims for damages for personal injury, including death, which may arise from operations under this contract, whether such operations be by himself, or by any sub-contractor, or anyone directly or indirectly employed by either of them. Certificates of such insurance shall be filed with the Chief Engineer, if he so requires, and shall be subject to his approval for adequacy of protection.

14. Indemnity

The Contractor shall indemnify and save harmless the Company from and against all losses and all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description made, brought or recovered against the Company by reason of any act or omission of the Contractor, his agents or employees, in the execution of the work, or in guarding the same.

In case no bond is furnished the Company may require indemnity insurance in amount, form and substance, satisfactory and acceptable to the Company, which insurance shall provide for the protection of the Company against failure of the Contractor to comply with the conditions of this covenant. The Contractor shall take out and pay the premiums on such insurance.

15. Superintendence

The Contractor shall constantly superintend all of the work embraced in this contract, in person or by a duly authorized representative acceptable to the Company.

16. Notice—How Served

Any notice to be given by the Company to the Contractor under this contract shall be deemed to be served if the same be delivered to the person in charge of the office used by the Contractor, or to his representative at or near the work, or deposited in the postoffice, postpaid, addressed to the Contractor at his last known place of business.

17. Protection

Whenever the local conditions, laws or ordinances require, the Contractor shall furnish and maintain, at his own cost and expense, necessary passageways, guard fences and lights and such other facilities and means of protection as may be required.

18. Timely Demand for Points and Instructions

The Contractor shall provide reasonable and necessary opportunities and facilities for setting points and making measurements. He shall not proceed until he has made timely demand, upon the Engineer for, and has received from him, such points and instructions as may be necessary as the work progresses. The work shall be done in strict conformity with such points and instructions.

19. Preservation of Stakes

The Contractor shall carefully preserve bench marks, reference points and stakes, and in case of wilful or careless destruction, he will be charged with the resulting expense and shall be responsible for any mistakes that may be caused by their unnecessary loss or disturbance.

20. Report Errors and Discrepancies

If the Contractor, in the course of the work, finds any discrepancy between the plans and the physical conditions of the locality, or any errors or omissions in plans or in the layout as given by points and instructions, it shall be his duty to immediately inform the Engineer, in writing and the Engineer shall promptly verify the same. Any work done after such discovery, until authorized, will be done at the Contractor's risk.

21. Inspection

All work and material shall be at all times open to the inspection, acceptance or rejection of the Engineer or his authorized representative. The Contractor shall give the Engineer reasonable notice of starting any new work and shall provide reasonable and necessary facilities for inspection even to the extent of taking out portions of finished work; in case the work is found satisfactory, the cost of taking out and replacement shall be paid by the Company. No work shall be done at night without the previous approval of the Engineer.

22. Defective Work or Material

Any omissions or failure on the part of the Engineer to disapprove or reject any work or material shall not be construced to be an acceptance of any defective work or material. The Contractor shall remove, at his own expense, any work or material condemned by the Engineer, and shall rebuild and replace the same without extra charge, and in default thereof the same may be done by the Company at the Contractor's expense, or in case the Chief Engineer shall not consider the defect of sufficient importance to require the Contractor to rebuild or replace any imperfect work or material, he shall have power, and is hereby authorized, to make an equitable deduction from the stipulated price.

23. Work Adjacent to Railway or Other Property

Wherever the work embraced in this contract is near the tracks, structures or buildings of the Company or of other railways, or persons, the Contractor shall use proper care and vigilance to avoid injury to persons or property. The work shall be so conducted as not to interfere with the movement of trains or other operations of the railway; or, if in any case such interference be necessary, the Contractor shall not proceed until he has first obtained specific authority and directions therefor from the proper designated officer of the Company and has the approval of the Engineer.

24. Rights of Various Interests

Wherever work being done by Company forces or by other contractors is contiguous to work covered by this contract, the respective rights of the various interests involved shall be established by the Engineer, to secure the completion of the various portions of the work in general harmony.

25. Order and Discipline

The Contractor shall at all times enforce strict discipline and good order among his employees and any employee of the Contractor who shall appear to be incompetent, disorderly or intemperate, or in any other way disqualified for or unfaithful to the work entrusted to him, shall be discharged immediately on the request of the Engineer, and he shall not again be employed on the work without the Engineer's written consent.

26. Contractor Not to Hire Company's Employees

The Contractor shall not employ or hire any of the Company's employees without the permission of the Engineer.

27. Order of Completion; Use of Completed Portions

The Contractor shall complete any portion or portions of the work in such order of time as the Engineer may require. The Company shall have the right to take possession of and use any completed or partially completed portions of the work, notwithstanding the time for completing the entire work or such portions may not have expired; but such taking possession and use shall not be deemed an acceptance of the work so taken or used or any part thereof. If such prior use increases the cost of or delays the work, the Contractor shall be entitled to such extra compensation, or extension of time, or both, as the Chief Engineer may determine.

28. Changes

The Company shall have the right to make any changes that may be hereafter determined upon, in the nature or dimensions of the work, either before or after its commencement, and such changes shall in no way affect or void the obligations of this contract. If such changes make any change in the cost of the work, an equitable adjustment shall be made by the Chief Engineer to cover the same, but the Contractor shall not claim compensation for anticipated profits.

29. Extra Work

No bill or claim for extra work or material shall be allowed or paid unless the doing of such extra work or the furnishing of such extra material shall have been authorized in writing by the .... Engineer.

The price for such work shall be determined by the Chief Engineer, who may either fix a unit price or a lump-sum price, or may, if he so elects, provide that the price shall be determined by the actual cost, to which shall be added .... per cent to cover general expenses and superintendence, profits, contingencies, use of tools, Contractor's risk and liability. If the Contractor shall perform any work or furnish any material which is not provided in this contract, or which was not authorized in writing by the Engineer, said Contractor shall receive no compensation for such work or material so furnished, and does hereby release and discharge the Company from any liability therefor.

If the Contractor shall proceed with such extra work or the furnishing of such extra material after receiving the written authority therefor, as hereinbefore provided, then such work or material, stated in the written authority of the Engineer, shall be covered, governed and controlled by all the terms and provisions of this contract, subject to such prices as may be agreed upon or fixed by the Chief Engineer.

If the Contractor shall decline or fail to perform such work or furnish such extra material as authorized by the Engineer in writing, as aforesaid, the Company may then arrange for the performance of the work in any manner it may see fit, the same as if this contract had not been executed, and the Contractor shall not interfere with such performance of the work.

30. Unavoidable Delays; Extension of Time on Parts of Work

If the Contractor shall be delayed in the performance of the work from any cause beyond his control, he may, upon written application to the Chief Engineer within three days of such delay, be granted such extension of time, as the Chief Engineer, shall deem equitable and just.

31. Suspension of Work

The Company may at any time stop the work, or any part thereof, by giving .... days' notice to the Contractor in writing. The work shall be resumed by the Contractor within ten (10) days after the date fixed in the written notice from the Company to the Contractor so to do. The Company shall not be held liable for any damages or anticipated profits on account of the work being stopped, or for any work done during the interval of suspension. It will, however, pay the Contractor for expense of men and teams necessarily retained during the interval of suspension; provided the Contractor can show that it was not reasonably practical to move these men and teams to other points at which they could have been employed. The Company will further pay the Contractor for time necessarily lost during such suspension at the rate of .... per cent per annum on the estimated value of materials, equipment and fixtures furnished by the Contractor on the work which is necessarily idle during such suspension, said rate of .... per cent per annum being understood to include depreciation, interest and insurance. But if the work, or any part thereof, shall be stopped by the notice in writing aforesaid, and if the Company does not give notice in writing to the Contractor to resume work at a date within .... of the date fixed in the written notice to suspend, then the Contractor may abandon that portion of the work so suspended and he will be entitled to the estimates and payments for work done, on such portion so abandoned, as provided in Section 41 of this contract.

32. Failure of Performance by Contractor

(a) If the Chief Engineer of the Company shall at any time be of the opinion that the Contractor is neglecting to remedy any imperfections in the work, or is not progressing with the work as fast as necessary to insure its completion within the time and as required by the contract, or is otherwise violating any of the provisions of this contract, the Chief Engineer, in behalf of the Company, shall have the power, and it shall be his duty to notify the Contractor in writing to remedy such imperfections, proceed more rapidly with said work, or otherwise comply with the provisions of this contract.

(b) If on the expiration of ten (10) days after the serving of such written notice upon the Contractor, the Contractor shall continue to neglect the work and shall fail to satisfy the Engineer of his efforts, ability and intentions, to remedy the specified deficiencies, the Company may terminate the employment of the Contractor and may take possession of the work and of all materials, tools and appliances thereon, and employ such means as may be, in the Engineer's judgment, necessary to finish the work. In such case the Contractor shall receive no further payment until the work shall be finished, when, if the unpaid balance that would be due under this contract exceeds the cost to the Company of finishing the work, such excess shall be paid to the Contractor; but if such cost exceeds such unpaid balance, the Contractor shall pay the difference to the Company.

(c) Upon failure of the Contractor to comply with any notice given in accordance with the provisions thereof, the Company shall have the alternative right, instead of assuming charge of the entire work, to place additional forces, tools, equipment and materials on parts of the work for the purpose of carrying on such parts of the work, and the Contractor shall be allowed therefor the contract price. The Company may retain the amount of the cost of such work, with .... per cent added, from any sum or sums due or to become due the Contractor under this contract.

33. Annulment Without Fault of Contractor

The Company shall have the right at any time, for reasons which appear good to it, to annul this contract upon giving notice in writing to the Contractor, in which event the Contractor shall be entitled to the full amount of the estimate for the work done by him under this contract up to the time of such annulment, including the retained percentage. The Contractor shall be reimbursed by the Company for such expenditures as in the judgment of the Chief Engineer are not otherwise compensated for, and as are required in preparing for and moving to and from the work; the intent being that an equitable settlement shall be made with the Contractor.

34. Removal of Equipment

In case of annulment of this contract before completion from any cause whatever, the Contractor, if notified to do so by the Company, shall promptly remove any part or all of his equipment and supplies from the property of the Company, failing which the Company shall have the right to move such equipment and supplies at the expense of the Contractor.

35. Settlement for Wages

Whenever, in the opinion of the Chief Engineer, it may be necessary for the progress of the work to secure to any of the employees engaged on the work under this contract any wages which may then be due them, the Company is hereby authorized to pay said employees the amount due them or any lesser amount, and the amount so paid them, as shown by their receipts, shall be deducted from any moneys that may be or become payable to said Contractor.

36. Failure to Make Payments

Failure by the Company to make payments at the times provided in this contract shall give the Contractor the right to suspend work until payment is made, or at his option, after thirty (30) days notice in writing, should the Company continue to default, to terminate this contract and recover the price of all work done and materials provided and all damages sustained, and such failure to make payments at the times provided shall be a bar to any claim by the Company against the Contractor for delay in completion of the work, due to such suspension or failure to pay.

37. Liens

If at any time there shall be evidence of any lien or claim for which the Company might become liable, and which is chargeable to the Contractor, the Company shall have the right to retain out of any payment then due or thereafter to become due, an amount sufficient to completely indemnify the Company against such lien or claim, and if such lien or claim be valid, the Company may pay and discharge the same, and deduct the amount so paid from any moneys which may be or become due and payable to the Contractor.

38. Monthly Estimate

So long as the work herein contracted for is prosecuted in accordance with the provisions of this contract, and with such progress as may be satisfactory to the Chief Engineer, the said Chief Engineer will, on or about the first day of each month, make an approximate estimate of the proportionate value of the work done and of acceptable material furnished or delivered upon the Company's property at the site of the work, up to and including the last day of the previous month. The amount of said estimate after deducting .... per cent and all previous payments, shall be due and payable to the Contractor at the office of the Treasurer of the Company on or before the .... day of the current month.

It is understood and agreed that the monthly estimates and certificates on unfinished work shall, in no case, be taken as an acceptance of the work, or a release of the Contractor from responsibility therefor, and that in computing the final estimate, the Chief Engineer need not be bound by the preceding estimates and certificates.

39. Cleaning Up

The Contractor shall, as directed by the Engineer, remove from the Company's property and from all public and private property, at his own expense, all temporary structures, rubbish and waste materials, resulting from his operations.

40. Acceptance

The work shall be inspected for acceptance by the Company promptly upon receipt of notice in writing that the work is ready for such inspection.

41. Final Estimate

Upon the completion and acceptance of the work, the Chief Engineer shall issue a final estimate over his signature, covering work provided for in this contract, completed and accepted by him, under the terms and conditions thereof, whereupon the balance found to be due the Contractor, including the retained percentage, shall be paid to the Contractor at the office of the Treasurer of the Company within .... days after the date of said final estimate, provided that, before the payment of said final estimate, the Contractor shall submit evidence satisfactory to the Chief Engineer that all payrolls, material bills and outstanding indebtedness in connection with the work have been paid.

This Contract shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

In Witness Whereof, the parties hereto have executed this contract, in ...., the day and year first above written .

....

Witness: (Contractor)

.... By ....

Attest:

(Company)

.... By ....

[3]FORM OF BOND

Know All Men by These Presents:

....

That the undersigned ....

...........................are held and bound unto the ....

....in the sum of ....

.........................dollars, lawful money of the United States of America (or Canada, as the case may be), to be paid to said .... its successors and assigns, to which payment the undersigned, jointly and severally, bind themselves, their heirs, executors, administrators, successors and assigns.

The condition of this obligation is that if .... Contractor, shall faithfully furnish and do everything required in the contract, executed in writing, dated ...., 19.... between .... Contractor, and .... Company for ....

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[3] Adopted, Vol. 16, 1915, pp. 101, 1037.

this obligation shall become of no effect; otherwise it shall continue in full force.

Signed, sealed and delivered this .... day of ...., 19...

ATTEST:

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[4]FORM OF AGREEMENT FOR INTERLOCKING PLANT

THIS AGREEMENT, made this .... day of ...., 19....., by and between .... hereinafter called the ....A...... Company and ....hereinafter called the ....B... Company.

WITNESSETH:

WHEREAS, ...
....
....
....
....

(Note.—Include brief description of conditions, including the location of existing or proposed grade crossing; an enumeration of all existing agreements, if any; the names of the companies between which agreements were made, their dates, purpose, etc.)

WHEREAS, the parties hereto mutually desire to construct, maintain, renew and operate an interlocking plant at said crossing, the location of said crossing and the arrangement of the interlocking plant to be as shown on the plan marked Exhibit A, dated .... identified by the signatures of the .... of the ....A....... Company, and of the .... of the ....B... Company, hereto attached, and hereby made a part of this agreement.

NOW, THEREFORE, in consideration of the premises and of the mutual conditions and agreements hereinafter set forth, the parties hereto covenant and agree as follows: ....
....
....
....

Definition

1. The term Interlocking Plant, herein contained, shall be held and taken to include any and all houses, towers, power plants, machinery, appliances and appurtenances required for its operation.

Construction

2. The .... Company agrees to construct an interlocking plant, as shown on said Exhibit A, and in accordance with specifications which

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[4] Adopted, Vol. 19, 1918, pp. 358, 1177; Vol. 29, 1928, pp. 92, 1266.

have been approved by the .... of the parties hereto, and identified by their signatures.

The ....A.......Company agrees to begin the construction of said interlocking plant within .... days after the execution of this agreement, and to carry the work forward to a prompt completion.

Apportionment of Cost

3. (a) The cost of removing any existing safety appliances or devices shall be divided in like manner as the maintenance and renewal expense of said appliances or devices has heretofore been divided.

(b) The cost of constructing, maintaining and renewing said interlocking plant, as shown on said Exhibit A, shall be borne by the parties hereto as follows: ....

....

....

....

....

....

Note.—It is recommended that the A.R.A. Signal Section table of signal and interlocking units be used.)

Each party hereto shall participate in the ownership of said interlocking plant in the ratio which the payments made by it for construction of said interlocking plant, including extensions and changes chargeable to capital account, bear to the total cost of construction thereof.

(c) The cost of maintaining and renewing said interlocking plant shall include taxes, assessments and insurance; all losses by fire, flood or other damage caused by the elements, strikes or other such contingencies, also any expense made necessary by an act, law or ordinance, of a lawfully constituted public authority.

(d) The cost of operating said interlocking plant, including the wages of the operators and signal men together with the cost of power, heat, light, and supplies, shall be borne by the parties hereto as follows:

......A.... Company ....

....

......B.... Company ....

....

Any other expenses properly chargeable to operations, shall be borne by the parties hereto in the same proportion as provided for maintenance in paragraph 3 (b).

Extensions and Changes

4. Either party shall have the right to make extensions or changes in said interlocking plant, provided that they shall not impair its efficiency. Such extensions or changes, arising from changes made in any existing track or tracks, or made to cover any future track or tracks or connections, which either party hereto may have the right to construct or which may be required by reason of any changes made in the standard appliances or practices of either party, or which may be ordered by a lawfully constituted public authority, shall be made by the .... Company, and

the cost of such extensions or changes shall be borne by the party hereto for whose benefit said extensions or changes are made, and the proportion chargeable to each party for maintenance, renewal and operation in such case shall be determined as follows: ....

....

....

Control of Plant

5. MAINTENANCE. (a) The maintenance and renewal of said interlocking plant shall be under the sole charge and control of the ....A..... Company, and it shall employ competent persons to maintain and renew the same, and such employees shall be removed for good and sufficient reason upon request in writing of a general managing officer of the ....B...... Company.

Each of the parties hereto, through its authorized employees and representatives, shall have the right at all times to inspect said interlocking plant, also the accounts covering its construction, maintenance, renewal and operation; and in the event that the............B..... Company shall notify the ....A.... Company, in writing, of repairs and renewals that may be necessary for the safe and proper operation of said interlocking plant, and if the ....A... Company neglects for a period of thirty days to make said necessary repairs and renewals, then the ....B.... Company shall have the right to make such repairs and renewals, and the ....A... Company shall, upon presentation of proper bills, and within the time provided in Section 8 hereof, pay its proportion of the amount so expended.

(b) Each of the parties hereto shall, at its own expense, keep all signals, switches, derails, and their connections, in or along its own tracks free from ice, snow, dirt or other obstructions which may interfere in any way with the proper working of said interlocking plant; and in case either party fails to do so, the other party may enter upon the premises of the party at fault and remove such ice, snow, dirt or other obstructions; in which event, the party at fault shall reimburse the party doing such work, as provided in Section 8, for all expense thereby incurred.

OPERATION. (c) The operation of said interlocking plant shall be under the sole charge and control of the ....A... Company, and it shall employ competent persons to operate the same. Such employees shall be removed for good and sufficient reasons upon request in writing of a general managing officer of the ....B...Company.

Either party may use the operators at said interlocking plant in its telegraph or telephone service, provided said party shall give the other party at least ten days prior written notice of such intention; but in the event that additional expense is so incurred, either on account of increased wages of operators over levermen, or on account of additional employees required, the party using the operators in its service shall bear the additional expense. Should both parties hereto require additional service, the cost shall be borne by each party in proportion to service rendered. If for any reason it becomes necessary to temporarily take said interlocking plant out of service, the control of the flagmen required to protect the crossing shall also be in the .... Company, and the expense of said flagmen shall be considered, for the purpose of apportionment, as an expense of operating said interlocking plant.

Material and Labor Supplied by Parties

6. Each of the parties hereto shall furnish and install its own derails, switch points, switch rods, special switch and derail ties and timbers, all track insulations, poles, crossarms, pins and insulators, and will maintain and renew them from time to time thereafter; and shall do all the track work and grading along its own tracks necessary to prepare the tracks for the installation of said interlocking plant, and shall provide and maintain proper drainage, and bear the cost and expense of raising and adjusting pipe carrier and mechanism foundations, or the renewal of detector bars, clips or any other appliance required or made necessary by the resurfacing, reballasting or rail renewal of its tracks within the limits of said interlocking plant.

Either party shall have the right to carry its automatic block signaling through the limits of the interlocking plant at its own expense. Where signals perform the function of both block and interlocking signals, the party hereto whose train movements are controlled by said block signals shall maintain them at its expense, provided, however, that work within home signal limits shall be done by plant maintaining party, or under its supervision, at expense of owning company.

Precedence

7. In the use of said interlocking plant, passenger, mail and express trains shall have precedence over freight trains and light engines; and freight trains shall have precedence over light engines. The trains and engines of the ....A.... Company shall have precedence over the trains and engines of like class of the ....B.. Company.

Payment of Bills

8. All payments hereunder shall be made within thirty days after rendition of proper bills.

The .... Company shall render bills covering the cost of constructing said interlocking plant, such expense to be billed in one statement unless otherwise agreed upon by the parties hereto.

Bills covering the maintenance, renewal and operation of said interlocking plant shall be rendered monthly; and those covering insurance, taxes and assessments, annually.

Such of said bills as are based upon payroll cost of labor and stock prices of material shall include a fair arbitrary charge to cover supervision, inspection, handling, transportation, accounting and similar undistributed items of expense. Such fair arbitrary charge shall be in accordance with the recommendations of the General Managers' Association of ...., in effect from time to time, or in the absence of any such recommendations, shall be agreed to by the parties, or determined by arbitration as hereinafter provided.

Should dispute arise as to the correctness of any items included in bills rendered under this agreement, the party against which such bills are rendered shall pay all items concerning which there is no dispute, and the other items shall be paid promptly when the correctness thereof has been ascertained.

Liability

9. Each party hereto assumes for itself the responsibility and risk of using and operating its own trains and engines over the space covered by said interlocking plant, and also responsibility for the negligent acts and omissions of its own officers, agents and employees engaged in connection therewith; and in performance of any of its separate duties under this contract; and will pay to the other party and to third persons all damages which may arise and for which it may be liable, arising from such negligence and in such operation.

The party having special charge of the management and operation of said interlocking plant shall not be liable to the other party for the negligent acts or omissions of any person employed in the construction, maintenance, renewal or operation of said interlocking plant, but all persons so employed shall, as respects any injury caused by such negligence, be regarded and treated as the agents or employees of each party hereto, and each of said parties hereby assumes the responsibility for all damages resulting from the negligence of such agents or employees in the operation of its own engines, cars and trains, and those of its tenants, lessees and licensees, at said crossings, and shall indemnify and save the other party harmless therefrom. Any expense caused by or growing out of the injury of any workman or employee engaged upon the construction of said interlocking plant shall be held and considered to be a construction expense and shall be divided as provided in Section 3.

Arbitration

10. In case any question arises under this agreement or concerning the subject-matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole disinterested arbitrator, to be selected jointly by the parties to this agreement.

The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as may be determined by the arbitrator.

Cancellation of Conflicting Agreements

11. It is mutually understood and agreed that any and all agreements existing between the parties hereto or their predecessors, so far as they conflict, or are inconsistent with the terms and conditions of this agreement, are hereby annulled, but in all other respects they shall continue in full force and effect.

Duration and Succession

12. This agreement shall take effect on the .... day of ...., 19...., and shall continue in force during the existence and operation of the interlocking plant, or until discontinued by the mutual agreement of the parties hereto.

The provisions of this agreement shall be binding upon and inure to the benefit of the parties hereto, their successors, lessees and assigns.

In Witness Whereof, the parties hereto have caused this agreement to be executed, in duplicate, by their respective officers, thereunto duly authorized, the day and year first above written.

Attest: ....
.... Company.
Secretary. By ....
Attest: ....
.... Company.
Secretary. By ....

[5]FORM OF AGREEMENT FOR CROSSING OF RAILWAYS AT GRADE

This Agreement, made this .... day of ....
in the year ...., by and between ....
hereinafter called ..the....A.....Company...............................
and ....
hereinafter called ..the...B.....Company..............................

Witnesseth:

Whereas, ...
....
....
....

(Note.—Include brief description of conditions, including the location of existing or proposed grade crossing, an enumeration of all existing agreements, if any; the name of the companies between which agreements are made, their dates, their purpose, etc.)

Whereas, the ....A.......... Company desires the right to construct, maintain, use and operate a railway crossing at grade across the tracks and right-of-way of the ....B....... Company to permit the passage of its trains over and across the right-of-way and tracks of the ....B.... Company and the ....A... Company is willing to grant said right; the location of said crossing and its proposed arrangement being shown upon a blueprint marked "Exhibit A," dated ...., identified by the signature of the .... of the ....A..... Company and of ....
.... of the ....B........ Company hereto attached and hereby made a part of this agreement; and

Whereas, the parties hereto have agreed upon the terms and conditions upon which said crossing as shown upon said Exhibit A shall be constructed, maintained and operated.

Now, Therefore, in consideration of the premises and in further consideration of the mutual covenants and agreements hereinafter stipulated to be kept and performed, it is mutually agreed between the parties hereto, for the purpose of defining the terms and conditions upon which said crossing shall be constructed, maintained, renewed and operated, as follows:

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[5] Adopted, Vol. 20, 1919, pp. 217, 914.

Definition

1. The term crossing as herein contained shall include rail, crossing frogs, track fastenings, crossing timbers, and other track appliances, included between the outer joints of one or more crossings installed or hereafter installed; together with ballast, drainage, side ditches, subdrainage, and other substructure appliances, devices or supports on the right-of-way of .... Company in so far as affected by said crossings; all necessary buildings, including flagmen's houses, shanties or towers; gates, semaphores and other safety devices or appliances; all as may be required to keep said crossing in safe and suitable condition for the operation of trains, as required by .... Company or by lawfully constituted public authority.

Grant

2. The ...."A"......... Company hereby grants to the ...."B"... Company, subject to the conditions and stipulations of this agreement, the right to construct, maintain, renew and operate at grade .....twos.......... track s...................... of the .... Company, over and across the right-of-way and tracks of the ...."A"... Company at the point of crossing, as shown on Exhibit A.

Construction

3. The ...."B"... Company agrees to construct a railway crossing at grade as shown on Exhibit A and according to detail plans and specifications, which have been approved by the .... Engineer of the ...."A". Company and identified by .... signature. The ...."B"... Company agrees to begin the construction of said crossing within .... days after the execution of this agreement and to carry the same forward continuously to prompt completion.

Apportionment of Cost

4. The cost of constructing, maintaining, renewing and operating said crossing shall be borne by the respective parties hereto as follows: ....
....
....
....
....
....
....

In the cost of maintaining and renewing said crossings shall be included the expense for taxes, assessments, and insurance; any losses by fire, floods and other damage caused by the elements; also any change made necessary by an act or ordinance of a lawfully constituted public authority, except as herein otherwise provided.

Extensions and Changes

5. (a) The .... Company reserves the right to construct, maintain, renew and operate upon its right-of-way from time to time such other additional track or tracks as it may deem necessary or desirable crossing the track or tracks of the ....

Company, the right to construct which is herein granted, and all the provisions and stipulations herein contained shall apply to such other additional track or tracks.

(b) The .... Company reserves the right to change the grade of its track or tracks as shown on Exhibit A not to exceed .... feet, and the grade of the crossing shall be changed to conform thereto. The expense of so changing shall be borne as follows:

....

....

....

....

....

....

(c) Either company shall have the right at its own expense to make minor changes in alinement at said crossings, provided that this shall not materially interfere with the tracks of the other party, but nothing herein contained shall be interpreted to cover major changes in grade or alinement, such as separation of grade or elevation of tracks required or brought about by laws or ordinances of properly constituted public authorities.

(d) Improvements or devices which may be necessary in order to conform to the standard practice of the ....A.... Company shall be provided as required by that Company, and the expense shall be borne in accordance with the provisions of Section 4 hereof.

(e) The privileges hereinbefore granted are granted upon the further express condition that whenever anything may be done or may be required to be done by the Chief Engineer of the .... Company, or under and in pursuance of any of the laws of the State of ...., or of any lawful action of proper public authorities in respect to said crossing, including the installation of gates, signals or interlocking, the .... Company shall make all changes at said crossing and in present or future tracks of both companies and their appliances, necessary to comply with or carry out the requirements of the Chief Engineer of the .... Company or of law, or action of such authorities, and the cost thereof shall be apportioned in accordance with Section 4 hereof.

(f) It is further understood and agreed that the .... Company will pay the cost of any connecting or transfer track or tracks that may, at any time, be required at or near the point of the crossing aforesaid, whether such track or tracks be ordered by competent authority, or put in by agreement between the parties hereto. If the junction switches of said connecting track or tracks in the main track or tracks of either of the parties hereto shall be or come to be within the limits of an existing interlocking plant, said junction switches shall be taken into the protection of said interlocking plant and the cost shall be borne as follows:

....

....

....

....

....

....

Maintenance and Renewal

6. The crossing shall be maintained by the .... Company. In case the .... Company shall remove its tracks or any of them at said crossing, the track or tracks of the .... Company shall be restored by the .... Company to their original condition, to the satisfaction of the Chief Engineer of the .... Company, and at the sole cost and expense of the .... Company.

Control

7. The maintenance, renewal, operation and protection of said crossing shall be under the sole charge and control of the .... Company, and it shall employ competent persons to maintain, renew and protect the same, and such parties from time to time so employed shall be removed for good and sufficient reason upon request in writing of a general managing officer of the .... Company.

Each of the parties hereto, through its authorized employees and representatives, shall have the right at all times to inspect said crossing, as well as the accounts covering the construction, maintenance, renewal and operation of the same; and in the event that the .... Company shall notify the .... Company in writing of renewals and repairs that may be necessary for the safe and proper operation of said crossing, and if the .... Company neglects for a period of thirty days to make said necessary renewals and repairs, then the .... Company shall have the right to make such renewals and repairs, and the .... Company shall, upon presentation of proper bills, and within the time provided in Section 11 hereof, pay its proportion of the amount so expended.

Protection

8. During construction and thereafter, flagmen or signalmen shall be furnished for the proper protection of said crossing, and such persons from time to time so employed shall be removed for good and sufficient reasons, upon request in writing of a general managing officer of the .... Company. The expense for their wages together with the cost of materials and supplies required in connection with their work, shall be apportioned as herein in Section 4 provided. Until interlocking protection shall have been provided, all trains shall approach said crossing under full control, and shall come to a full stop within .... feet from said crossing, and shall not proceed until the receipt of a proper signal so to do.

9. The .... Company reserves the right, so long as it maintains fence up to the point of intersection of the .... Company's track with the respective boundary lines of the .... Company's premises, to require the .... Company to build and maintain in good order, proper stockguards at the point of intersection aforesaid, for the purpose of preventing trespass upon said Company's premises from the track or grounds of said .... Company.

10. If the .... Company shall (during the life of this contract) electrify its railroad at the said crossing, upon ....

days written notice to the .... Company, the .... Company agrees to furnish, maintain and install such electric appliances, fixtures and appurtenances at said point of crossing as may be necessary for the safe and convenient operation of said crossing, and to the satisfaction of the .... Company's Engineer.

Precedence

11. In the use of said crossing, passenger, mail and express trains shall have precedence over freight or work trains and light engines, and freight or work trains shall have precedence over light engines. The trains and engines of the .... Company shall have precedence over the trains and engines of like class of the .... Company.

Ownership

12. Each of the respective parties hereto shall participate in the ownership of the crossing in the proportion which the payments made by it for construction of same bear to the total cost of construction.

Payment of Bills

13. The payment of all bills under this agreement shall be made not later than the twenty-fifth day of the month following the month in which said bills are rendered. The bills for expense of construction shall be made as a final bill, unless otherwise mutually agreed and understood.

Bills covering maintenance, renewals and operation, taxes and assessments shall show total expenditures, and proportions chargeable to each of the respective parties hereto, and shall be rendered monthly; those covering insurance, taxes and assessments annually.

Should any dispute arise as to the correctness of any of the items included in bills rendered, under this agreement, the party against which any such bill is rendered shall pay as herein provided an amount equal to the sum of all items in said bill, the correctness of which is unquestioned. The remainder, covering disputed items, shall be paid promptly as herein provided, upon an adjustment of the dispute.

Added Percentages

14. In making bills for the cost and expense of constructing, renewing, maintaining, operating and protecting said crossing, all labor and material shall be charged for at actual cost, plus .... per cent added to material, and .... per cent to labor to cover freight charges or accruals, handling, superintendence, use of tools and accounting, except that work done by contract shall have no percentages added.

Such of said bills as are based upon payroll cost of labor and stock prices of material shall include a fair arbitrary charge to cover supervision, inspection, handling, transportation, accounting and similar undistributed items of expense. Such fair arbitrary charge shall be agreed to by the parties, or determined by arbitration as hereinafter provided.

The provision as to actual cost herein contained shall not be considered or held as a warrant for charging excessive prices or freight rates on material, for hauling the same unreasonable distances, nor for the payment of unreasonable arbitrary charges of any kind.

Liability

15. Each party hereto assumes for itself the responsibility and risk of using and operating its own trains and engines over the space covered by said crossing, and also responsibility for the negligent acts and omissions or the alleged negligent acts or omissions of its own officers, agents, servants and employees engaged in connection therewith; and in performance of any of its separate duties under this contract; and will pay to the other party and to third persons all damages which may arise and for which it may be liable arising from such negligence and in such operation.

The party having special charge of the management and operation of said crossing shall not be liable to the other party for the negligent acts or omissions, or the alleged negligent acts or omissions of any person employed in the operation, maintenance or repair of said crossing, but all persons so employed shall, as respects any injury caused by such negligence, be regarded and treated as the agents or servants of each party hereto, and each of said parties hereby assumes the responsibility for all damages resulting from the negligence of such agents or servants in the operation of its own engines, cars and trains, and those of its tenants, lessees and licensees, at said crossing, and shall indemnify and save each of the other parties harmless therefrom. Any expense caused or growing out of the injury of any workman or employee engaged upon the construction of said crossing shall be held and considered to be a construction expense, and shall be divided as herein in Section 4 provided.

Arbitration

16. In case of any difference or dispute arising under this agreement or concerning the subject-matter thereof, the parties hereto agree to submit such difference or dispute to three arbitrators, one of whom shall be appointed by the .... Company, and another by the .... Company, and each party shall give to the other party written notice of appointment of its arbitrator, together with his name and address. The two arbitrators so chosen shall select a third arbitrator. If either party shall fail to choose an arbitrator as herein provided, the arbitrator selected by the other party hereto, at the expiration of .... days after the date of its said written notice, shall select a second arbitrator, and the two arbitrators so chosen shall select a third arbitrator. If within .... days after the appointment of a second arbitrator, as herein provided, the two so chosen shall have failed to select a third arbitrator, either party hereto may apply to any judge of the District Court of the United States for the District which shall then include

....

....

who shall thereupon appoint the third arbitrator. The three arbitrators so chosen in any manner as herein provided, or a majority of them, shall hear and decide said difference or dispute, and their decision, or that of a majority of them, shall be final and binding on the parties hereto.

The expense of an arbitration under the terms hereof shall be borne by the parties hereto in the proportions fixed by the arbitrators.

Cancellation of Conflicting Agreements

17. It is mutually understood and agreed that any and all agreements relative to said crossing, existing between the parties hereto or their predecessors, so far as they conflict, or are inconsistent with the terms and provisions of this agreement, are hereby annulled, but in all other respects they shall continue in full force and effect.

Duration and Succession

18. This agreement shall remain in full force and effect as long as the tracks of the respective parties cross at grade at the location shown upon Exhibit A.

The provisions of this agreement shall be binding upon and inure to the benefit of the parties hereto, their successors, lessees and assigns.

IN WITNESS WHEREOF, the parties have caused these presents to be executed in duplicate by their respective officers as of the day and year first above written.

ATTEST:

.... Company

Secretary By ....

ATTEST:

.... Company

Secretary By ....

[6]FORM OF LEASE AGREEMENT FOR INDUSTRIAL SITE

Parties

1. THIS LEASE, made this .... day of ...., 19...., between the ...., a corporation, the Lessor, hereinafter called the Railway Company, and ...., having a principal office or place of business in the ...., County of ...., and State of ...., hereinafter called the Lessee,

WITNESSETH:

That the Railway Company, in consideration of the rents to be paid and agreements to be performed by the Lessee, hereby leases unto the Lessee all those certain premises, situated in the .... County of ...., State of ...., described as follows:

Description

2. ....

....

....

....

....

....

....

....

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[6] Adopted, Vol. 24, 1923, pp. 508, 1188.

....

....

in accordance with plan numbered ...., dated ...., designated as ...., hereto attached and made a part hereof.

Purpose

3. The said premises shall be used for ....

....

Term

4. To have and to hold the same from ...., 19...., to ...., 19...., unless sooner terminated, as hereinafter provided.

Termination

5. Either party hereto may terminate this lease at any time, by giving to the other party .... days written notice to that effect. Acceptance of rent in advance by the Railway Company shall not act as a waiver of the right to terminate this lease.

Notice

6. Any written notice given by the Railway Company to the Lessee shall be deemed to be properly served if the same be delivered to the Lessee, or one of Lessee's agents, or if posted on said premises, or if mailed, postpaid, addressed to the Lessee at Lessee's last known place of business.

Rent

7. The Lessee shall pay to the Railway Company a rental of .... per .... payable .... in advance, beginning 19....

Refund

8. Rent paid in advance for a period extending beyond the termination of this lease shall be refunded to the Lessee, unless such termination shall be on account of violation or non-fulfillment of any of the terms of this lease by the Lessee, or on account of abandonment of said premises by the Lessee, in which case the amount paid as rental shall be retained by the Railway Company.

Taxes

9. The Lessee shall pay all taxes, licenses and other charges which may be assessed or levied upon said premises, including improvements thereon, and upon the business of the Lessee upon said premises, or against the Railway Company by reason of occupation or use of said premises by the Lessee.

Assignment

10. This lease shall not be assigned or in any manner transferred nor said premises or any part thereof sublet, used or occupied by any party

other than the Lessee, nor for any purpose other than that specified herein, without the written consent of the Railway Company.

Abandonment

11. The failure of the Lessee to occupy or use said premises for the purpose herein mentioned for .... days at any one time shall be deemed an abandonment thereof. An abandonment of said premises by the Lessee shall, at the option of the Lessor, operate as an absolute and immediate termination of this lease without notice.

Improvement

12. The Railway Company hereby gives to the Lessee the privilege of erecting, maintaining and using on said premises, suitable buildings and other structures for the aforesaid purposes; provided that such buildings and other structures shall be approved by the .... of the Railway Company, and thereafter maintained and painted to the satisfaction of the Railway Company.

Clearance

13. The Lessee agrees not to permit any obstruction over any railway track or tracks on said premises, less than .... feet above top of rail, or alongside of said track or tracks less than .... feet from center of track, with the necessary additional clearance on curves.

Removal of Improvements

14. Upon the termination of this lease in any manner, the Lessee shall deliver to the Railway Company the possession of said premises, remove all the improvements placed thereon by the Lessee, and restore said premises to substantially their former state. Should the Lessee fail, within .... days after the date of termination of this lease, to make such removal or restoration, then the Railway Company may, at its election, either remove said improvement and restore said premises to substantially their former state at the sole cost of the Lessee, or may take and hold the said improvements as its sole property.

Inflammables

15. No goods of an explosive, dangerous or inflammable nature shall, in any case, be stored in or upon said premises without the written consent of the Railway Company.

Condition of Premises

16. The Lessee shall at all times keep said premises in a safe, clean and sanitary condition, and shall not mutilate, damage, misuse, alter or permit waste therein.

Right of Inspection

17. The said premises shall be open at all reasonable times for inspection by the Railway Company, its agents, and authorized applicants for purchase or lease.

Advertising

18. No advertising shall be placed on said premises without the written permission and approval of .... of the Railway Company.

Laws and Regulations

19. The Lessee shall, without cost to the Railway Company, comply with all laws, rules, regulations and ordinances affecting said premises.

Miscellaneous Charges

20. The Lessee shall pay all charges for water, lighting, street sprinkling, sweeping and oiling, that may be levied or assessed against said premises, during the period of occupancy.

Snow and Ice

21. The Lessee shall at all times keep the sidewalks abutting said premises free from snow and ice, and any expense to the Railway Company by reason of the failure of the Lessee so to do shall be paid by the Lessee to the Railway Company upon demand therefor; such expense to include all loss of or damage to property and injury to or death of persons.

Use of Tracks

22. The Lessee shall not allow any tracks to be constructed or operated upon said premises without the written consent of the Railway Company.

Liability

23. The Lessee agrees to indemnify the Railway Company and save it harmless from any and all claims and expenses that may arise or may be made for death, injury, loss or damage resulting to the Railway Company's employees or property, or to other persons or their property, by reason or in consequence of the occupancy or use of said premises by the Lessee.

Forfeiture

24. Any breach of any covenant, stipulation or condition herein contained to be kept and performed by the Lessee, shall be sufficient cause for the immediate termination of this lease.

Insolvency or Bankruptcy

25. If the Lessee at any time during the continuance of this agreement should become insolvent or bankrupt, or if Lessee's affairs should be placed in the hands of a Receiver, then this lease shall, at the option of the Railway Company, terminate, and the Railway Company shall have the right to resume and retake possession of said premises without any accountability whatsoever to the Lessee or to Lessee's estate.

Renewal

26. A lawful continuance of the tenancy beyond said term shall be deemed a renewal thereof for the further term of .... to end at the expiration thereof, without further notice; and every further lawful continuance shall be deemed a further renewal for a like term, to end in like manner, and every renewal or holding over shall be subject to the provisions of this lease.

Until terminated as hereinbefore provided, this lease shall inure to the benefit of and be binding upon the parties hereto, their heirs, executors, administrators, successors, and assigns.

In Witness Whereof, the parties hereto have executed this lease on the day and year first above written.

Witness:

....

Railway Company.

By ....

Witness:

....

Lessee.

By ....

[1]FORM OF AGREEMENT FOR INDUSTRY TRACK

THIS AGREEMENT, made this .... day of ...., 19...., between ....
hereinafter called the Railway Company, and ....
hereinafter called the Industry;

Witnesseth:

Whereas, the Industry desires track facilities, hereinafter called sidetrack, for the economical and convenient conduct of the business of the Industry, at or near .... Station, County of ...., State of ...., described as follows: ....

....

....

....

....

....

....

....

in accordance with plan numbered ....
dated ...., designated as ....
hereto attached and made a part hereof:

Now, Therefore, in consideration of the covenants and agreements herein contained, it is mutually agreed that the said sidetrack shall be constructed and maintained, and the Railway Company hereby agrees to operate the same under the following terms and conditions: ....

....

....

....

....

....

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....

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....

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[1] Adopted, Vol. 24, 1923, pp. 515, 1185, 1188; Vol. 29, 1928, pp. 102, 1268.

Right-of-Way

1. The Industry shall provide, without cost to the Railway Company, all necessary right-of-way outside of the right-of-way of the Railway Company, required for the proper construction and operation of said sidetrack, said right-of-way to be satisfactory to the .... of the Railway Company.

The cost and expense of procuring or complying with any ordinance, order, permit or consent whatsoever required by municipal, State or other lawfully constituted authorities for the construction, maintenance, operation and use of said sidetrack shall be borne by the Industry.

The Railway Company shall have the right to enter upon the property of the Industry, for the purpose of constructing, maintaining and operating said sidetrack.

Construction

2. The cost of constructing said sidetrack, including roadbed, trestles, bridges and all other appurtenances in connection therewith, shall be borne as follows: ....
....
....
....
....
....
....
....
....
....
....

Maintenance

3. Said sidetrack shall be maintained (including removal of ice and snow) and renewed to the satisfaction of the .... of the Railway Company; the work shall be performed and the cost thereof borne as follows: ....
....
....
....
....
....
....
....
....
....
....

Ownership

4. The title and ownership of said sidetrack shall be vested as follows: ....
....
....
....

....

....

....

....

....

....

....

....

Use

5. The Railway Company shall have the right to use the whole or any part of said sidetrack, provided such use shall not unreasonably interfere with the use thereof by the Industry.

Neither party hereto shall permit or authorize the use of said sidetrack by or for the benefit of any other person, firm or corporation not one of the parties hereto, without the written consent of the other party. The Industry shall not assign this contract or any rights thereunder without the written consent of the Railway Company.

Changes or Enlargement

6. If any change, rearrangement, extension or enlargement of said sidetrack or its structures shall at any time be necessary by reason of any change in the Railway Company's track or tracks, or because of any changes in the operating practice of the railway, the Railway Company shall not be required to bear any expense resulting therefrom.

Clearances

7. The industry agrees not to permit any obstruction over said sidetrack, less than .... feet above top of rail, or alongside of said sidetrack less than .... feet from center of track, with the necessary additional clearance on curves.

Liability

8. It is understood that the movement of railway locomotives involves some risk of fire, and the Industry assumes all responsibility for and agrees to indemnify the Railway Company against loss or damage to property of the Industry or to property upon its premises, regardless of railway negligence, arising from fire caused by locomotives operated by the railway on said sidetrack, or in its vicinity for the purpose of serving said Industry, except to the premises of the Railway and to rolling stock belonging to the Railway or to others, and to shipments in the course of transportation.

The Industry also agrees to indemnify and hold harmless the Railway Company for loss, damage or injury from any act or omission of the Industry, its employees, or agents, to the person or property of the parties hereto and their employees, and to the person or property of any other person or corporation, while on or about said sidetrack; and if any claim or liability other than from fire shall arise from the joint or concurring negligence of both parties hereto it shall be borne by them equally.

Discontinuance

9. Any and all loss or damage sustained by the Industry in consequence of any temporary or permanent elimination of said sidetrack, shall be assumed by the Industry, or in event the disposition of the property of the Railway Company, or its future use or development shall make it impracticable in the judgment of the .... of the Railway Company to continue the connection, the Industry hereby waives any and all claims therefor.

Cancellation, Termination and Removal

10. This agreement shall be terminable upon .... (......) days written notice from either party to the other.

Upon termination of this agreement the Railway Company shall have the right to enter upon the property of the Industry and remove any or all of the material owned by the Railway Company, and shall not be liable to account in any way to anyone for any monies paid or expended on account of any of the track or tracks covered by this agreement, nor for any damages resulting from the removal of any or all of the material owned by the Railway Company.

Until terminated as hereinbefore provided, this agreement shall inure to the benefit of and be binding upon the parties hereto, their heirs, executors, administrators, successors and assigns.

In Witness Whereof, the parties hereto have executed this agreement in .... the day and year first above written.

Witness:

....

Railway Company.

By ....

Witness:

....

Industry.

By ....

[8]FORM OF LICENSE FOR PRIVATE ROAD CROSSING

The ...., hereinafter called the Railway Company, hereby gives to ...., hereinafter called the Licensee, the license and privilege of constructing, maintaining and using
an overhead
a grade crossing over the lands and right-of-way and over
an undergrade across
under
the tracks of the Railway Company situated in .... and substantially as shown on the plan hereto attached, designated as .... and dated .... and made a part hereof:

1. The term of this License shall date from ...., 19..., and shall continue until terminated by a written notice given by either party to the other at least .... days prior to the date of termination.

---

[8] Adopted, Vol. 24, 1923, pp. 528, 1189.

2. The Licensee shall pay to the Railway Company as consideration for said license and privilege the sum of .... on the .... day of every .... during the continuance of this license, and pro rata for a shorter period; a proportionate part of said consideration to be refunded to the Licensee in case of termination hereof by the Railway Company prior to the date to which the consideration shall have been paid.

3. The Licensee shall, at its own expense, construct and maintain said crossing in compliance with all statutory regulations and to the satisfaction of the Railway Company, and under the Railway Company's supervision and direction, and except in case of emergency, shall do no work with reference to the maintenance of said crossing except under such supervision and direction, and after reasonable notice in writing to the Railway Company. The Railway Company may, at its option, construct and maintain such crossing and, in such event, the Licensee shall pay to the Railway Company the entire cost and expense of all labor performed and materials furnished by the Railway Company in constructing and maintaining said crossing.

4. The Licensee shall provide and maintain such protection, by signs or otherwise, as the Railway Company may consider necessary.

User 5. The Licensee shall permit said crossing to be used only by the Licensee's agents and servants and by persons having business with the Licensee.

6. The Licensee shall not obstruct or interfere with the passage of the Railway Company's trains. The Licensee shall indemnify and save harmless the Railway Company against all claims or payments on account of loss, damage or expense to the property either of the Licensee, or the Railway Company, or others, or to the persons of the Licensee, the Railway Company's agents and servants, or others, which may be due directly or indirectly to said crossing, even if such loss, damage or expense may be due to contributory negligence by the Railway Company.

7. The Licensee shall, on request of the Railway Company, remove said crossing from the premises of the Railway Company or make such changes in said crossing as may be required by the Railway Company, if such removal or changes shall in the judgment of the Railway Company be needed in connection with the development or use of the premises of the Railway Company. The Railway Company may, at its option, do such work and in such event the Licensee shall pay to the Railway Company the entire cost and expense of all labor performed and materials furnished by the Railway Company in connection with such work.

In Witness Whereof, the parties hereto have executed their agreement to this License this .... day of ...., 19....

Witness:

....

Railway Company.

By ....

Witness:

....

Licensee.

By ....

[9]FORM OF AGREEMENT FOR TRACKAGE RIGHTS

Note—In writing the agreement, the condensed names of the Grantor and the Grantee should be used where terms (Grantor) and (Grantee) are shown in form; as, Central Company and the Pennsylvania Company.

THIS AGREEMENT, made this .... day of ....
19...., by and between ....
(Corporate name of Grantor)
a corporation organized and existing under the laws of the State of ...., hereinafter called the ......"A"...Company..........
(Condensed name of Grantor)
and ....
(Corporate name of Grantee)
a corporation organized and existing under the laws of the State of ...., hereinafter called the .."B"...Company..........
(Condensed name of Grantee)

WITNESSETH:

WHEREAS, the .... owns or operates a certain
(Grantor)
portion of the railway, extending ....
....
....
....
....
....
....
....

And WHEREAS, the .....B.........Company.............. wishes
(Grantee)
to acquire the right to use the same and the ......A....Company........
(Grantor)
is willing to grant such use.

NOW, THEREFORE, in consideration of the premises and of the mutual conditions and agreements hereinafter set forth, the parties hereto covenant and agree as follows:

Grant

1. The ...A....Company..
(Grantor)
hereby grants to the ...B...Company..
(Grantee)
and the ..."B"...Company.................... agrees to exercise during the
(Grantee)
term and subject to the provisions of this agreement, the right to use jointly with the ...."A" Company..............................
(Grantor)
and any other parties to whom the ....A...Company..........
(Grantor)
may grant similar right, the ....
(Grantor's)
railway between .... and ....
a distance agreed upon for the purposes of this agreement as ....
.... (......) miles and the rights to move thereover its own through trains, hauled by its own motive power.

---

[9] Adopted, Vol. 25, 1924, pp. 193, 1254.

Description

2. The facilities covered by this agreement are herein referred to as the "joint section." A schedule thereof as of the effective date of this agreement, together with the values agreed upon for the purposes of this agreement only, is attached hereto, marked Schedule .... and is hereby made a part hereof.

The tracks included in said joint section are shown in red lines on the map marked:

....

....

which is hereto attached and hereby made a part of this agreement.

The joint use hereby granted shall include the property and appurtenances which the ...."A" Company... (Grantor) may at its option find necessary to construct and maintain for the safe and prompt passage of trains over the joint section during the life of this agreement.

Connections

3. The ....B. Company.. (Grantee) shall, at its own expense, construct the necessary connections between its tracks and the tracks of the ...A. Company................ (Grantor) at ...., and shall thereafer properly maintain and operate the same at its own expense, and shall indemnify, protect and save harmless the ....A. Company.............. (Grantor), its successors and assigns, from all loss or damage which they or any of them may suffer or become liable for, on account of, or growing out of, the construction, maintenance or operation of said connection. Any switch connections in the track of the ......"A"...Company........... (Grantor) shall be constructed and maintained by the ....A.....Company........... (Grantor) at the expense of the ....B..Company............ (Grantee)

Changes in Interlocking

4. If it shall be found necessary to install any interlocking plant, signal device or other safety appliances, or make changes in any existing interlocking plant, signal device or other safety appliances resulting from any and all of said connections between the tracks of the parties hereto, such extensions shall be made and the expense shall be borne on the following basis: ....

....

....

....

....

....

Conditions of Use

5. The right of use hereby granted to the ......B...Company..... (Grantee) is the right to run trains manned by the employees of the ...."B"...Company.... (Grantee) over the joint section, but not to do

any local freight, passenger or express business within the limits of said joint section.

Management

6. The "A" Company.......... shall have entire charge and control
(Grantor)
of the operation and maintenance of the joint section, the use of which is hereby granted to the ......"B" Company...........................
(Grantee)

Rental

7. The ...."B" Company..................... agrees to pay to the
(Grantee)
.... during the continuance of this agreement:
(Grantor)

(a) A sum equivalent to ....of the interest at the rate of .... per cent (......%) per annum on .... Dollars ($..........), hereby agreed upon between the parties hereto as the value of said joint section as of the effective date of this agreement;

(b) A sum equivalent to .... of the interest, at like rate, on all assessments and on the cost of additions, extensions, improvements and betterments used by the ...., which may from time
(Grantee)
to time be made to said joint section;

(c) A sum equivalent to .... of the taxes assessed against said joint section;

(d) A sum equivalent to .... of the depreciation and obsolescence on structures as listed in the following schedule:

....
....
....
....
....
....
....
....
....
....
....
....
....
....

NOTE.—See alternate bases for rental at end of this form.

(e) That proportion of the cost and expense of operation and maintenance of said joint section which the car and engine mileage of the .... thereover in each month shall bear to the
(Grantee)
total car and engine mileage (each engine to be counted as two cars) thereover in such month; insurance to be included in operation and maintenance.

(f) All bills shall be payable monthly, 30 days after rendition. To the cost of all material there shall be added, and from all credits for scrap or secondhand material there shall be deducted fifteen per cent (15%).

Other Tenants

8. In event of any other company or companies being granted a similar right to the joint use of said joint section or any part thereof, bills for rental under paragraphs (a), (b), (c) and (d) hereof shall be subject to a proportionate reduction with respect to the facilities used by any other company or companies.

Express Business

9. Neither party to this agreement shall have any agreement with any Express Company for carrying express matter upon or over said joint section which will in any way interfere with the rights of the other party to carry its express matter or messengers on or over the same.

Telephone and Telegraph Lines

10.

....

....

....

....

....

....

Rights of Trains

11. Trains of a superior class of either party shall have preference over trains of inferior class of both parties. Trains of the .... shall have preference over trains of the .... of the same class.

Schedule and Time Tables

12. Joint schedules for the movement of trains over said joint section shall be made by the ....
(Grantor)

The expense of printing time tables and supplements thereto shall be borne by the party requesting the change of time, or if made necessary by a general change of time it shall be borne on the basis of operating expense.

Operation and Maintenance

13. Each party to this agreement shall furnish, without expense to the other party, all labor, fuel and train supplies necessary for the operation of its own trains. The ....
(Grantor)
shall furnish all other labor, materials and supplies necessary for the operation and maintenance of said joint section, the expense to be divided in accordance with the provisions of Section 7 (e). The joint section shall be maintained in a condition considered necessary by either party for its best class of service over said joint section.

Joint Employees

14. All persons employed for the common benefit of the parties hereto, in the maintenance or use of the said joint section, shall, while so employed, be considered as joint employees. Persons engaged partly in the maintenance or use of said joint section shall be considered as joint employees only while engaged in the work for the joint use and benefit of both parties. Train

employees except employees of work trains working on the joint section shall not be considered joint employees.

Removal of Employees

15. If any employee of the ....B...Company... (Grantee) shall neglect or refuse to abide by the rules and regulations established by the ....A...Company...... (Grantor) governing the operation and maintenance of said joint section, such employee upon written request of the...... ....A. Company...... (Grantor) shall be prohibited from working upon or over said joint section.

Bonding

16. All employees collecting or receiving money so far as concerns the business or revenue of the ....B...Company.... (Grantee) shall be the employees of that company and shall report and remit direct to it. The ....B.........Company.... (Grantee) may bond such employees or require them to furnish bonds, and the ....A...Company.... (Grantor) shall not be liable to the ....B...Company......... (Grantee) for their neglect or default.

Liability

17. Liability for all loss of or damage to property and injury to or death of persons (all hereinafter collectively referred to as damage), in any manner originating or occurring upon or in connection with the operation of the property and facilities covered by this agreement, shall be governed by the following provisions:

For the purposes of this article, all property, the joint use of which is herein granted, shall be considered the joint property of the parties hereto; and employees of either party engaged in or charged with the duty of the operation, care or maintenance of the property and facilities covered by this agreement shall be considered joint employees of the parties hereto.

Each party hereto shall be liable for all damage to whomsoever occurring, which shall be caused in any manner by or in connection with its trains, engines, cars, business or traffic, when the trains, engines, cars, business or traffic of the other party are in nowise involved.

Each party hereto shall be liable for all damage to whomsoever occurring which shall be caused solely:

(a) By defect in its sole property or property separately used by it.
(b) By act or by the negligence of its separate employees.

Otherwise, each party shall be liable for all damage to its separate property, employees or traffic. All other damage and costs and expenses in connection therewith, including those resulting from undetermined causes, shall be borne equally by the parties hereto.

Each party shall adjust the claims of its own passengers and employees, but no settlement for which the other party is to be held wholly responsible, and no settlement in excess of Five Hundred Dollars ($500.00), for which the other party is to be held jointly responsible, shall be made without its concurrence.

Clearing Wrecks

18. The .... shall promptly pick up and remove
(Grantor)
all wrecks which occur on the joint section.

All equipment and salvage so picked up, which belongs to or is being handled in the business of the .... shall be
(Grantee)
promptly delivered to it.

The cost of picking up and removing wrecks, including rental for equipment used in connection therewith, shall be borne in accordance with the provisions of Section 17 hereof.

Suits

19. In event of any suit being brought against either party hereto, for which the other party may be held liable, the party against whom such suit is brought shall at once give the other party notice in writing thereof in order that the other party may make such defense as it may deem proper, and in such case the party that is liable as herein provided shall pay all attorneys' fees, costs and expenses incurred in defending such suit, as well as damages that may be recovered therein.

Interruption of or Delay to Traffic

20. During any time traffic over the joint section is interrupted, the
.... shall not be required to furnish the
(Grantor)
.... use of any other of its tracks. The
(Grantee)
.... shall make its own arrangements for
(Grantee)
detouring its trains and shall assume the entire cost thereof.

Neither party shall under any circumstances have any cause of action against the other for loss or damage of any kind caused by or resulting from such interruption or delay to its business.

Examination of Accounts

21. The accounts of the ...., so far as they
(Grantor)
relate to the valuation or expenses of operation and maintenance of said joint section, shall be open at all reasonable times to the inspection of the proper officers of the ....
(Grantee)

Default

22. If the .... shall make default in any
(Grantee)
of the payments hereinbefore required of it to be made, or shall fail to faithfully perform any of the covenants herein required by it to be performed, then in such case, and if such default or failure shall continue for a period of .... (.....) days after the ....
(Grantor)
shall have given the .... a written notice thereof, the
(Grantee)
.... may, by a .... (......) days
(Grantor)
notice in writing to the .... declare this agreement
(Grantee)
terminated, and may at the termination of the .... (......)
days in said notice mentioned, exclude the ....
(Grantee)
from the use and enjoyment of any and all of the premises and rights

hereinbefore granted to it and the .... shall surrender
(Grantee)
to the .... all of said premises, and shall have no
(Grantor)
claim or demand upon it by suit at law or otherwise, on account of such exclusion. Provided that failure to make any payment or perform any covenant which is the subject of arbitration or of litigation between the parties hereto, shall not, pending arbitration or litigation, be deemed a cause of forfeiture hereunder.

The .... may waive any such default or
(Grantor)
failure, but no action of the .... in waiving
(Grantor)
such default or failure shall extend to, or be taken to affect any subsequent default or failure, or impair its rights.

Arbitration

23. In case any question arises under this agreement or concerning the subject-matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole disinterested arbitrator to be selected jointly by the parties to this agreement.

The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as may be determined by the arbitrator.

Term

24. This agreement shall take effect on the .... day of ...., 19....., and shall continue in force for the period of .... years from said date and thereafter until terminated on a date specified by a written notice given to either party by the other party at least .... prior to such date of termination.

Successors

25. All the covenants and agreements herein contained shall be binding upon and inure to the benefit of the successors and assigns of the respective parties hereto, provided, however, that the ....
(Grantee)
shall not assign or transfer the rights hereby granted to it, without the written consent of the ....
(Grantor)

Execution

26. In Witness Whereof, the parties hereto have executed this agreement the day and year first above written.

....
(Corporate name of Grantor)
By .... President.

Attest:
....
Secretary.

....
(Corporate name of Grantee)
By .... President.

Attest:
....
Secretary.

ALTERNATE BASES FOR RENTAL

NOTE.—In the place of the provisions of Section 7 the rental may be a lump sum or may be on the basis of train miles.

In any case the elements which usually enter into the expense on which rental is based are as given in Section 7.

[10]FORM OF LICENSE FOR WIRES, PIPES, CONDUITS, DRAINS, HOPPER PITS AND OTHER STRUCTURES ON RAILWAY PROPERTY

THIS AGREEMENT, made this .... day of ...., 19....., by and between the ...., hereinafter called the Railway Company, and ....
having a principal office or place of business in.....................................,
hereinafter called the Licensee,

WITNESSETH:

WHEREAS, the Licensee desires to construct, maintain and use ....
....
....
....
....
upon the property of the Railway Company, situated ....
...., and substantially as shown on the plan hereto attached, designated as ....,
dated ...., and made a part hereof:

It is mutually agreed as follows:

1. The Railway Company grants permission to the Licensee to construct, maintain and use .... upon the property of the Railway Company, in accordance with said plan and the specifications forming a part hereof, and subject to the requirements of the Railway Company.

2. In consideration of this license, the Licensee shall pay to the Railway Company, in advance, the sum of ....
.... per ...., beginning
....

3. Every cost and expense of construction, maintenance, use and removal resulting from this license, shall be paid by the Licensee. The Railway Company may perform, without notice, any work which it considers necessary to the safe operation of the Railway. The Licensee shall do no work under this license, which may interfere with the operation of the Railway without the written permission of the Railway Company.

4. Use of the property of the Railway Company, however long continued, shall not create any estate or easement in the Licensee or any rights other than license.

5. The Licensee shall indemnify, protect, and save harmless, the Railway Company from and against all claims, suits, costs, charges, and damages, made upon or incurred by the Railway Company in connection with this license.

---

[10] Adopted, Vol. 22, 1921, 254, 995; Vol. 25, 1924, pp. 201, 1254.

Termination 6. This agreement may be terminated by either party by .... notice to the other party, or without notice on disuse by the Licensee for ....

and Notice 7. Any notice given by the Railway Company to the Licensee shall be deemed to be properly served if the notice be delivered to the Licensee, or if left with any responsible agent of the License, or if mailed, postpaid, addressed to the Licensee at the last known place of business of the Licensee.

Removal 8. Upon termination hereof the Licensee shall forthwith remove all the Licensee's constructions from the property of the Railway Company, to the satisfaction of the Railway Company. In case of the Licensee's failure so to do, the Railway Company may at its option either retain such constructions or remove them at the cost of the Licensee.

Assignment 9. This agreement shall not be assigned or in any manner transferred, without the written consent of the .... of the Railway Company.

10. Until terminated as hereinbefore provided, this agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

IN WITNESS WHEREOF, the parties hereto have executed this agreement on the day and year first above written.

WITNESS:

....

Railway Company

By ....

WITNESS:

....

Licensee

By ....

off

[11]FORM OF AGREEMENT FOR PLACING SNOW OR SAND FENCES ~~BEYOND~~ THE RAILWAY COMPANY'S PROPERTY ~~LINE~~

THIS AGREEMENT, made this .... day of ...., 19......, between .... (hereinafter called the Licensor) and .... (hereinafter called the Railway Company),

WITNESSETH:

That the Licensor hereby grants to the Railway Company, its successors and assigns, the right to erect and thereafter to maintain upon the land of the Licensor at .... linear feet of snow/sand fence commencing at a point .... in accordance with plan numbered ...., dated ....,

---

[11] Adopted, Vol. 25, 1924, pp. 211, 1255.

designated as ....
hereto attached and made a part hereof, together with the right to enter upon the lands of the Licensor from time to time, for the purpose of erecting, maintaining and renewing said fence and removing the same from the premises of the Licensor.

Said fence may be erected and maintained by the Railway Company from the .... day of .... to the .... day of .... in each year.

This agreement shall take effect as of the .... day of ...., 19......, and shall continue until terminated by a written notice given by either party to the other at least 60 days prior to the date of termination.

The Railway Company agrees to pay to the Licensor as consideration for the privileges herein granted a rental of .... Dollars per year, payable annually in advance upon the ....day of every ....

In Witness Whereof, the parties hereto have executed this agreement the day and year first above written.

Witness:

....
Licensor

Witness:

....
Railway Company
By ....

[12]FORM OF AGREEMENT FOR JOINT USE OF PASSENGER STATION FACILITIES

THIS AGREEMENT, made this .... day of .... 19......, by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the ......"A"...... Company; and ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the ......"B"...... Company.

Witnesseth:

That, in consideration of the covenants and agreements herein contained, it is mutually agreed as follows:

Grant and Description

1. The ......"A"...... Company hereby grants to the ......"B"...... Company the right to use, during the life of this agreement, jointly with the ......"A"...... Company and any other railway company or companies, now using or which the ......"A"...... Company may hereafter permit to use, the Passenger Station facilities of the ......"A"...... Company at ...., in the County of .... and State of ...., described as follows:

---

[12] Adopted, Vol. 26, 1925, pp. 502, 1362.

All being substantially as shown on plan numbered ...., dated ...., designated as .... signed by the .... of the respective companies, hereto attached and made a part hereof.

Scope

2. The right of joint use hereby granted contemplates and is confined to the use by the ......"B"...... Company of the said Passenger Station facilities of the ....."A"..... Company for the accommodation of the passengers and conduct of the passenger, baggage, mail and express business of the ......"B"...... Company.

Employees

3. The ......"A"...... Company shall furnish to the ......"B"...... Company the joint services of the agents, clerks, telegraph operators, laborers, gatemen, watchmen and other employees of the ......"A"...... Company, whose services may be necessary for the conduct by the ....."B"..... Company of its said business at said station.

Operation and Maintenance

4. The ......"A"...... Company shall maintain the station and appurtenances owned by it and to be jointly used hereunder; shall pay all taxes and insurance; and shall provide the necessary light, heat, water and other accessories required for the joint use of the same; provided, however, that the ......"B"...... Company shall, at its own cost and expense, provide and furnish all stationery, printed forms, tickets and baggage checks which may be necessary for the conduct of its business.

Rental

5. The ......"B"...... Company shall pay to the ......"A"...... Company, in monthly settlement, for the privilege of using said passenger station facilities and for the service performed by it for the ......"B"...... Company, the following sums of money:

(a) Such proportion of the interest at the rate of .... per cent per annum upon the value of said facilities, which for the purpose of this agreement is hereby agreed to be the sum of .... as the number of .... of the ......"B"...... Company handled in and out of said station bears to the total number of .... handled in and out of the same, during such period.

(b) Such proportion of the expense incurred for the maintenance of said facilities, and properly chargeable under the rules, regulations and classification of the Interstate Commerce Commission to maintenance expense, as the number of .... of ......"B"...... Company handled in and out of said stations bears to the total number of .... handled in and out of same, during such period.

(c) Such proportion of the salaries or wages paid by ......"A"...... Company to the agent, clerks, telegraph operators, laborers, gatemen, watchmen and all other employees engaged in joint service, as the number of .... of ......"B"...... Company handled in and out of said station bears to the total number of .... handled in and out of the same, during such period.

(d) Such proportion of the cost of taxes and insurance, light, heat, water, telephone service and other accessories for joint use, as the number of .... of the ......"B"...... Company handled in and out of said station bears to the total number of .... handled in and out of the same, during such period.

Bills made under paragraphs (b) and (c) of this article will include 10 per cent of the cost of labor for supervision and use of tools, and 15 per cent of the cost of material for freight and handling.

Bills shall be rendered monthly and shall be paid within 30 days thereafter. (See Appendix.)

Additions and Betterments

6. In the event that any additions to, or betterments or improvements of, the facilities of the ......"A"...... Company, to be jointly used by the ......"B"...... Company hereunder, shall, at any time hereafter and during the life of this agreement, in the judgment of the ......"A"...... Company, be deemed to be necessary for the joint use of the parties hereto, then, and in such event, the ....."A"..... Company may, in its discretion, and without the concurrence of the ......"B"...... Company, make and construct the same, and thereafter the ......"B"...... Company shall pay additional rent for the joint use of said additions, betterments or improvements, and its additional proportion of the maintenance and operation of the same, on the basis provided in Article 5 of this agreement.

Custody of Property

7. All cars of the ......"B"...... Company and the contents thereof, while upon the said tracks of the ......"A"...... Company, as well as all freight, baggage, express or other property held by or for account of the ......"B"...... Company in, upon or about the said facilities of the ......"A"...... Company to be jointly used hereunder, shall, for the purpose of this agreement, be deemed and considered to be under the control and in the custody and care of the ......"B"...... Company and the ......"B"...... Company shall carry its own insurance upon the same.

Deprivation of Use

8. In case the ......"B"...... Company shall by reason of fire or other unavoidable casualty be deprived of the use of said facilities or any part thereof, a reduction of said rental shall be made to it for the time during which said deprivation shall continue proportionate to the amount of said deprivation.

Status of Employees

9. All employees of the ......"A"...... Company, whose services are necessary and required for the joint use of the parties hereto in the operation and maintenance for joint account of the passenger station facilities of the ......"A"...... Company shall, for the purpose of this agreement, be considered to be sole employees, in the performance of, or omission to perform, services, the benefit or other results of which accrues to either

party thereto, solely; and as joint employees, in the performance of, or omission to perform, services, the benefit or other result of which accrues to both parties hereto, jointly.

Liability

10. Liability for all loss of or damage to property and injury to or death of persons (all hereinafter collectively referred to as damage), in any manner originating or occurring upon or in connection with the operation of the property and facilities covered by this agreement, shall be governed by the following provisions:

Each party hereto shall be liable for all damage which shall be caused in any manner by or in connection with its trains, engines, cars, business or traffic, when the trains, engines, cars, business or traffic of the other party are in nowise involved.

Each party hereto shall be liable for all damage which shall be caused solely

(a) By defect in its sole property or property separately used by it.
(b) By act or by the negligence of its separate employees.

Otherwise, each party shall be liable for all damage to its separate property, employees or traffic.

All other damage and costs and expenses in connection therewith, including those resulting from undetermined causes, shall be borne equally by the parties hereto.

In interchange, the liability as between the delivering road and the receiving road shall be as follows:

Trains and cars in passenger, mail, express or like service which are presently to proceed in whole or in part to and upon the road of the other party hereto, shall be trains or cars of the delivering road:

(a) For determining questions arising in connection with the interchange of passengers and baggage; until such passengers are landed on the station platform or the bagage has been unloaded from the train and receipted for.
(b) For determining other questions; until the final stop in the station, if all the cars and engine are to proceed on the receiving road; or until the cars to be delivered are cut off, if all the cut is to proceed on the receiving road, and thereafter each part of such train shall be the train or cars of the road over whose rails it is to proceed. Intermediate cars in a train, which are to be cut out to proceed on the other road, shall become the cars of the receiving road when the first cut is made, and the cars to be returned to the original train shall remain throughout the movement, the cars of the delivering road.

Each party shall adjust the claims of its own passengers and employees. No settlement for which the other party is to be held wholly responsible, and no settlement in excess of Five Hundred Dollars ($500.00), for which the other party is to be held jointly responsible, shall be made without its concurrence.

In event of any suit being brought against either party hereto, for which the other party may be held liable, the party against whom such suit is brought shall at once give the other party notice in writing thereof in order that the other party may make such defense as it may deem proper, and in such case the party that is liable as herein provided shall pay all attorneys' fees, costs and expenses incurred in defending such suit, as well as damages that may be recovered therein.

Default

11. If the ......"B"...... Company shall make default in any of the payments hereinbefore required of it to be made, or shall fail to faithfully perform any of the covenants herein required by it to be performed, then in such case, and if such default or failure shall continue for a period .... (......) days after the ......"A"...... Company shall have given the ......"B"...... Company a written notice thereof, the ......"A"...... Company may, by a .... (......) days notice in writing to the ......"B"...... Company declare this agreement terminated, and may at the termination of the said .... (......) days in said notice mentioned, exclude the ......"B"...... Company from the use and enjoyment of any and all of the premises and rights hereinbefore granted to it and the ......"B"...... Company shall surrender to the ......"A"...... Company all of said premises, and shall have no claim or demand upon it by suit at law or otherwise, on account of such exclusion. Provided, that failure to make any payment or perform any covenant which is the subject of arbitration or of litigation between the parties hereto, shall not, pending arbitration or litigation, be deemed a cause of forfeiture hereunder.

The ......"A"...... Company may waive any such default or failure, but no action of the ......"A"...... Company in waiving such default or failure shall extend to, or be taken to affect any subsequent default or failure, or impair its rights.

Arbitration

12. In case any question arises under this agreement or concerning the subject matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole disinterested arbitrator, to be selected jointly by the parties to this agreement.

The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as may be determined by the arbitrator.

Term

13. This agreement shall take effect on the .... day of ...., 19......, and, unless earlier terminated as hereinbefore prescribed, shall continue in force for the period of .... years from said date and thereafter until terminated on a date specified by a written notice given to either party by the other party at least .... prior to such date of termination.

This agreement shall inure to the benefit of and be binding upon the parties hereto, their successors and assigns.

IN WITNESS WHEREOF, the parties hereto have executed this agreement, the day and year herein first above written.

THE ....COMPANY

By ....

President.

Attest:

....

Secretary.

THE ....COMPANY

By ....

President.

Attest:

....

Secretary.

Appendix

Under section (3) ......"B"...... Company may have separate agents, etc.

Section 5 may be written in various ways, depending on conditions and the agreement of the parties. The following are suggestions for alternates:

1. For one or more paragraphs of this section:
   A flat sum ....Dollars.
2. For paragraph (a):
   One-half of the interest at ....per cent of the value of such facilities, which for the purpose of this agreement shall be taken at $..........................

Should any other railway company or companies be granted by ......"A"...... Company the joint use of the aforesaid passenger facilities, then in that event the interest to be paid by ......"B"...... Company shall be that proportion which it bears to the total number of companies using the joint facilities.

3. A charge for depreciation and obsolescense may be made at the option of the parties.

[13]FORM OF OPTION FOR PURCHASE OF LAND

IN CONSIDERATION of .... Dollars, receipt whereot is hereby acknowledged, and for other good and valuable consideration, the undersigned (hereinafter called the Owner), for himself, his heirs, executors, administrators, successors and assigns, offers to convey to .... (hereinafter called the Railway Company), its successors and assigns, within .... days from the acceptance of this offer, the property described below free and clear of all liens and encumbrances by warranty deed for .... Dollars, payable as follows:

....

....

....

---

[13] Adopted, Vol. 26, 1925, pp. 508, 1364.

The Railway Company will also pay for examination of titles; interest, taxes, water rents, rents and insurance to be prorated as of the date of delivery of the deed.

This offer may be accepted at any time before twelve o'clock noon .... time on the .... day of ...., 19......, by delivering or mailing to the Owner or by filing with a telegraph company, notice of said acceptance, and until that date and hour this offer is irrevocable. Upon service of said notice, the Railway Company may immediately enter upon and take possession of the property described below.

In the event of acceptance of this offer the $............... above named shall be applied on the purchase price. If this offer is not accepted, said sum shall be retained by the Owner.

(Description of Property)

....

....

....

....

....

....

In Witness Whereof, the Owner has hereunto set his hand and seal in duplicate this .... day of ...., 19......

....

Owner.

Witness:

....

....

[11]FORM OF AGREEMENT FOR PURCHASE OF ELECTRICAL ENERGY

Note.—This Form of Agreement is not intended to be used in connection with purchase of a large volume of electrical energy for traction purposes.

THIS AGREEMENT, made this .... day of.................., 19......, by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company and .... hereinafter called the Electric Company.

Witnesseth:

1. The Electric Company agrees to sell and deliver to the Railway Company electrical energy for the Railway Company's requirements for power and lighting at .... during the continuance of this agreement up to .... K.W. demand, as hereinafter provided. Form of Energy

2. The electrical energy supplied under this agreement shall be in the

---

[11]Adopted, Vol. 27, 1926, pp. 448, 1342.

form of .... phase alternating current of .... cycles and .... volts, direct current of .... volts and shall be measured on the .... side of the .... Company's transformers.

[illegible] 3. The frequency and voltage at points of delivery shall be subject to the ordinary fluctuations incidental to the usual practice in generation and transmission of electrical energy, but the fluctuations incidental to the usual practice in generation and transmission of electrical energy shall not, except under unusual circumstances, beyond immediate control, exceed a maximum variation for

> alternating current of .... cycles above or below .... cycles and of .... volts above or below .... volts.
>
> direct current of .... volts, above or below .... volts.

Percentage of use 4. The Railway Company shall have the right to use electrical energy for lighting purposes up to .... per cent of the total connected power load.

Supply 5. The Electric Company agrees to have at all times a reserve capacity of equipment sufficient to insure continuity of supply of electrical energy up to the limit of the prevailing maximum demand of the Railway Company, against all reasonably possible failures of power generating, transmitting or converting equipment.

Rates 6. The Railway Company shall pay to the Electric Company monthly upon rendition of bills for electrical energy under this agreement:

> (a) a net fixed primary charge at the rate of .... per calendar year per K.W. of yearly maximum demand as determined by the indication of a standard instrument recording the highest average monthly demand in K.W., which demand shall be the average of the four highest demands, demand being defined as the greatest amount of power in K.W., taken simultaneously at the several points of measurement during any consecutive ...... minute period of any day of 24 hours.
>
> (b) a secondary charge of .... per K.W.H. for all electrical energy consumed, on the basis of readings of a meter or meters.

The type of measuring instruments and their location shall be mutually agreed upon and they shall be furnished by the Electric Company and installed at its expense.

The Railway Company agrees to maintain, at all times, a power factor of not less than ...... per cent. If the power factor of the Railway Company's load is less than ...... per cent, then the words "kilovolt-ampere-hours" shall be substituted for "K.W.H." in Section 6-b; and in consideration of this penalty, if the Railway Company maintains the power factor above ...... per cent, then the Electric Company agrees to allow a discount of ...... per cent for each 1 per cent that the power factor of the Railway Company's load is above ...... per cent.

In event the Electric Company supplies electrical energy to any consumer under conditions similar to and at rates lower than those herein provided, the Electric Company agrees to charge the Railway Company such lower rates in lieu of the rates provided for herein.

7. It is further agreed that the prices to be paid to the Electric Company under Section 6 for electrical energy consumed by the Railway Company are based upon cost of $\substack{\text{coal}\\\text{oil}}$ delivered f.o.b. alongside .... of .... per $\substack{\text{ton}\\\text{barrel}}$ of .... $\substack{\text{pounds}\\\text{gallons}}$ If at any time during the continuance of this agreement the cost of $\substack{\text{coal}\\\text{oil}}$ as aforesaid is increased or decreased, the Railway Company shall pay to the Electric Company, after such increase or decrease, an additional or lesser amount for the electrical energy consumed hereunder equal to ...... mills per K.W.H. for each ...... cents of such increased or decreased $\substack{\text{coal}\\\text{oil}}$ cost, respectively.

8. If at any time, by reason of strike, riot, insurrection, civil or military authority, fire, explosion, act of God, or any other cause beyond its control, the Railway Company is prevented, in whole or in part, from making use of the electrical energy to be supplied hereunder, or the Electric Company is unable to supply such electrical energy, then the minimum charge to the Railway Company shall be reduced in proportion to the inability of the parties to perform their respective obligations hereunder.

9. All meters shall be furnished and maintained by the Electric Company and shall be tested by approved methods by the Electric Company at its own expense during the months of .... and ...., and the Electric Company shall, where necessary, adjust or replace defective meters. The Electric Company shall give to the Railway Company at least .... days notice when each test is to be made and representatives of both parties shall be present thereat. If, upon test, a meter is found to be inaccurate, it shall be promptly restored to an accurate condition or a new meter shall be substituted; should any meter be found to register in excess of 2 per cent, either above or below normal, then correction in the readings of such meter shall be made for one-half of the inaccuracy found, provided the error is less than 10 per cent, and if the error is more than 10 per cent the electrical energy consumed shall be estimated by agreement between the parties, but no such correction shall be made in excess of 30 days prior to the date of the test and in no case prior to the date of the last prior test.

10. Bills shall be rendered and payable monthly and shall be subject to a ...... per cent discount if paid within .... days after rendition.

11. It is further agreed that the .... Company shall operate switches connecting the Railway Company's apparatus with the Electric Company's lines.

12. The Railway Company shall use reasonable care to prevent anyone other than the authorized employees of the Electric Company from interfering with meters or other appliances of the Electric Company.

13. In case any question arises under this agreement or concerning the subject-matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole disinterested arbitrator, to be selected jointly by the parties to this agreement. The expense of arbitration shall

be apportioned between the parties hereto or wholly borne by either party as may be determined by the arbitrator.

Access [illegible]

14. The Electric Company shall have the right of access to the premises of the Railway Company at all reasonable times during the period of this agreement for the purpose of reading meters and inspecting and repairing the Electric Company's equipment, and, on the termination of this agreement, for the purpose of removing its property.

Term

15. This agreement shall take effect as of the .... day of ...., 19..., and shall continue until the .... day of ...., 19..., and thereafter until terminated by written notice given by either party to the other at least ...... days prior to the date of termination.

Successors

16. This agreement and each provision herein contained is hereby made binding upon the legal representatives, successors and assigns of each party hereto.

In Witness Whereof, the parties hereto have executed this agreement the day and year first above written.

....
Company.

By ....
President.

Attest:

....
Secretary.

....
Company.

By ....
President.

Attest:

....
Secretary.

[15]FORM OF AGREEMENT FOR JOINT USE OF POLES ON RAILWAY RIGHTS-OF-WAY

Note.—This Form of Agreement is not intended to be used as a general agreement with a telegraph company operating on the lines of a railway company.

THIS AGREEMENT, made this .... day of ...., 19....., between the .... Railway Company (hereinafter called the Railway Company) and the .... Company, a corporation existing under the laws of the State of .... (hereinafter called the Wire Company), for the joint use by the parties of certain poles between .... and .... in ....

In consideration of the mutual promises herein contained, the parties hereby agree as follows:

---

[15] Adopted, Vol. 27, 1926, pp. 452, 1342.

1. It is agreed that the location of all the joint poles and joint use thereof by the parties shall be as set forth in Schedule A, in accordance with plan No. ....., dated ...., designated as ...., hereto attached and made a part hereof.

2. The proportionate interest of each of the parties in the poles and the proportion of the cost of construction and maintenance to be borne by each party shall be as set forth in Schedule A.

3. The available space on each of the said poles shall be occupied by the parties hereto in the manner shown on said plan.

4. Details of construction of said poles and the wires and fixtures thereto attached and the character and voltage of electric currents employed shall be governed by specifications No.......

5. Except in case of emergency no relocation or replacement shall be made of any joint pole except upon due written notice given by the party responsible for its maintenance to the other party occupying such pole. In emergency cases verbal notice shall be immediately given and confirmed in writing as soon as practicable.

6. Each party shall, at its own expense, place and maintain its crossarms, fixtures and wires and shall be responsible for the electric currents employed by it in the conduct of its business, for loss of or damage to property (including poles, wires and fixtures maintained under this agreement) and for injury to or death of persons due solely to the act or neglect of such party. Each party shall pay its fair proportion of any such loss of or damage to property or injury to or death of persons due in part to its act or neglect and in part to the act or neglect of the other party. In event the parties hereto cannot agree upon the fair proportion to be borne in any such case the question shall be referred to arbitration. Each party shall take reasonable precaution to prevent interference of its wires on said poles, or of its system, with the system or services of the other party.

7. The poles included herein shall be in the custody of and maintained by the party hereto indicated in said Schedule A, and the other party occupying such poles shall pay the proportion specified in said Schedule A of the expense of maintenance.

8. The Wire Company shall pay to the Railway Company as rent for the use of the latter's property and right-of-way the sum of $........ per pole per year on the .... day of every .... during the continuance of this agreement (and pro rata for a shorter period), a proportionate part of said rent to be refunded to the Wire Company in case of termination hereof by the Railway Company by notice, as provided in Section 13 hereof, prior to the date to which rent shall have been paid.

9. In event a pole tax or other similar charge is assessed by state or municipal authority upon said poles, or poles erected in renewal thereof, the same shall be treated as a maintenance expense.

10. Each party shall pay all taxes assessed against its crossarms, fixtures and wires or against its property or rights.

11. The net expense of construction or maintenance caused by a change of any pole with respect to size, character, location or otherwise, solely for the benefit of one of the parties shall be borne solely by such party and it shall have sole use of any additional space thus obtained, but

if any such change is for the benefit of both of the parties, the net expense thereof shall be borne by the parties in proportion to their respective benefit, and each shall have its fair share of the use of any additional space so obtained.

12. The party maintaining any pole or poles may with the consent of the other party hereto occupying said pole or poles, license the use of such poles by other parties, and a duplicate of each such license shall be filed with the other party hereto. All such licenses shall specify the terms and conditions governing such use. In case revenue is derived from the use of any pole or poles in such a license, the party granting the license shall collect such revenue and shall pay to the other party hereto its proportionate share thereof.

13. If one of the parties hereto desires to discontinue the use of any pole jointly owned hereunder, it shall give to the other party written notice of its intention so to do; and shall, within 90 days, remove its wires and fixtures and transfer all its interest in said pole to the other party if the other party desires to continue its use. It shall thereupon be paid its fair proportion of the original cost of the pole, less depreciation, and shall be released from all liability hereunder in connection with said pole except liabilities theretofore incurred. If such wires and fixtures are not so removed the other party hereto may at the expiration of said 90 days remove the same from such pole without being deemed guilty of trespass, injury or damage to the party discontinuing use of such pole, or its property or rights, and may collect all expense incurred in connection with making such removal.

14. This agreement shall take effect as of the .... day of ...., 19..., and shall continue until terminated by written notice given by either party to the other at least ...... days prior to the date of termination.

15. In event use of said poles is to be discontinued by both parties hereof, upon termination hereof each party shall at its own expense remove its crossarms, fixtures and wires from said poles and said poles shall be removed by the party responsible for the cost and maintenance thereof as indicated in said Schedule A and the net cost of removal of said poles shall be borne by the parties in the proportions applying to the cost of construction and maintenance as set forth in said Schedule A.

In Witness Whereof the parties have executed this agreement the day and year first above written.

....
Company.
By ....
Attest: President.
....
Secretary.

....
Company.
By ....
Attest: President.
....
Secretary.

[16]FORM OF AGREEMENT FOR FURNISHING WATER FROM RAILWAY WATER SYSTEMS TO EMPLOYEES AND OTHERS

THIS AGREEMENT, made this .... day of ...., 19...., by and between ...., a corporation organized and existing under the laws of the .... of ...., hereinafter called the Railway Company, and ...., hereinafter called the Consumer.

WITNESSETH:

That in consideration of the covenants and agreements herein contained, it is mutually agreed as follows:

1. The Railway Company agrees to make the connection between its water service lines and the pipe line of the Consumer at the point shown on the plan hereto attached and marked ....
....
....
and hereby made a part hereof, and to provide a water meter upon the connecting line of pipe serving the Consumer, and the Railway Company hereby permits the Consumer, as a matter of accommodation, and not as a legal right, to take and appropriate temporarily such surplus water, not to exceed .... $\substack{\text{gallons}\\\text{cubic feet}}$ per day, from the water system of the Railway Company as is available, and can be spared in the judgment of the proper officer of the Railway Company; it being expressly understood and agreed that the Railway Company is not engaged in the business of developing, supplying or distributing water to the Consumer, the public or any one else for domestic, manufacturing or any other purpose.

2. The Railway Company agrees to maintain said connection and meter.

3. The Consumer agrees to pay the Railway Company the cost of said connection and meter and of their maintenance.

4. The Consumer agrees to pay to the Railway Company for the water furnished by it at the rate of .... per $\substack{\text{1000 gallons}\\\text{100 cubic feet}}$

5. Water furnished under this agreement shall be for the sole use of the Consumer and water shall not be furnished to others than the Consumer through the Consumer's service line without the consent in writing of the .... of the Railway Company.

6. Bills for water furnished or other service performed by the Railway Company as herein provided shall be rendered monthly and shall be due and payable when rendered. In case of failure on the part of the Consumer to pay when due, the monthly bills for service performed or water furnished, the Railway Company shall have the right to discontinue the furnishing of water and terminate this agreement.

7. This agreement shall take effect on ...., 19...., and shall continue in force until terminated on a date specified by written notice given to either party by the other party to this agreement at least .... prior to such date of termination.

---

[16] Adopted, Vol. 28, 1927, pp. 466, 1435.

8. Upon termination, the Consumer shall pay to the Railway Company all costs of disconnecting and removing the connection between the water facilities of the Railway Company and the service line of the Consumer and all other expense incidental thereto.

9. This agreement shall not be assigned or in any manner transferred by the Consumer without the written consent of the .... of the Railway Company.

10. The Consumer agrees to indemnify the Railway Company and save it harmless from all claims and expenses that may arise or be made for loss or damage resulting to the employees or property of the Consumer or to any other persons or property, arising out of the construction, maintenance or operation of the water facilities used in furnishing water to said Consumer or the use of the water furnished as herein provided, or from failure, in whole or in part, to supply water from any cause whatsoever.

11. Until terminated as hereinabove provided, this agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

In Witness Whereof the parties hereto have executed this agreement the day and year first above written.

Witness

....

Railway Company

By ....

Witness

....

Consumer.

[17]FORM OF AGREEMENT FOR THE PURCHASE OF WATER

THIS AGREEMENT, made this .... day of ...., 19....,
by and between ...., a corporation organized and existing under the laws of the State..... of ...., hereinafter called the Water Company, and ...., a corporation organized and existing under the laws of the .State.... of ...., hereinafter called the Railway Company.

Witnesseth:

That in consideration of the covenants and agreements herein contained, it is mutually agreed as follows:

1. The Water Company agrees to supply the Railway Company with all the water it may require for ....

....

....

at ....

2. The Railway Company agrees to pay to the Water Company, upon rendition of bills therefor, for all water consumed, at the rate of .... per $\frac{\text{1000 gallons}}{\text{100 cubic feet}}$ determined by the reading of a meter or meters to be installed and maintained by the Water Company.

---

[17] Adopted, Vol. 28, 1927, pp. 468, 1435.

3. The Water Company agrees to use its best efforts to furnish an uninterrupted supply of water to the Railway Company, but it is understood and agreed that the Water Company shall not be liable for breaks in water pipe, failure of pumping apparatus or any other causes beyond it control.

4. This agreement shall take effect as of the .... day of ...., 19...., and shall continue for .... years and thereafter until terminated by written notice given by either party to the other at least .... prior to the date of termination.

In Witness Whereof the parties hereto have executed this agreement the day and year first above written.

Witness

....

Water Company

By ....

Witness

....

Railway Company

By ....

[16]FORM OF AGREEMENT FOR JOINT USE OF FREIGHT TERMINAL FACILITIES

THIS AGREEMENT, made this .... day of ...., 19...., by and between ...., a corporation organized and existing under the laws of the .... of .... hereinafter called the ..."A"...Company; and ...., a corporation organized and existing under the laws of the .... of .... hereinafter called the..."B"...Company.

Witnesseth:

That, in consideration of the covenants and agreements herein contained, it is mutually agreed as follows:

Permit and Description

1. The..."A"...Company hereby permits the..."B"...Company to use, during the life of this agreement, jointly with..."A"...Company and any other railway company or companies, now using or which the..."A"... Company may hereafter permit to use, the Freight Terminal and appurtenant facilities of the..."A"...Company at........in the........of........ and........of........described as follows:

(a) The Interchange Tracks designated by the..."A"...Company for delivering and receiving cars handled or to be handled for the..."B"... Company at said Freight Terminal and also cars interchanged between the parties.

(b) The Freight Station comprising freight houses, freight offices, platforms, cover sheds, driveways and house tracks.

(c) The Transfer Platform comprising platforms, cover sheds, office and cranes and appurtenant tracks.

(d) The Team Track Yard comprising yard office, tracks and driveways.

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[16] Adopted, Vol. 29, 1928, pp. 106, 1268.

(e) The Icing Station comprising icing plant and appurtenant tracks.

All being substantially as shown on plan........numbered........ dated........designated as...

....

signed by the............of the respective companies (hereto attached and made a part hereof).

Scope

2. The permission of joint use hereunder contemplated is confined to the use by the..."B"...Company of the said Freight Terminal and appurtenant facilities of the..."A"...Company for the sole purpose of conducting the freight business of the..."B"...Company.

Service

3. The..."A"...Company shall furnish and control all employees and appliances necessary in the judgment of the..."A"...Company for the operation of said Freight Terminal and appurtenant facilities.

(a) It is understood that any employee shall be removed from service in said Freight Terminal upon the written request of the..."B"...Company.

(b) The employees engaged in said Freight Terminal shall make such reports to the..."B"...Company from time to time as it may reasonably require, and any monies collected for the ..."B"...Company shall be considered as its funds and remitted as it may direct. The..."A"...Company shall not be responsible in any way for such collections and remittances and only agrees to use ordinary care in the selection of its employees.

(c) The..."B"...Company may bond any employee in said Freight Terminal it desires or may join with the..."A"...Company in bonding any such employee.

4. The..."B"...Company shall at its sole expense and as directed by the..."A"...Company switch from or to said Interchange Tracks or such other tracks in said Freight Terminal as may be designated from time to time by the..."A"...Company cars empty or containing freight handled or to be handled by the..."A"...Company for account of the..."B"... Company at said Freight Terminal.

The..."A"...Company shall inspect all cars placed on said Interchange Tracks for itself and for the..."B"...Company in accordance with the rules of the American Railway Association.

(a) A car brought into said Freight Terminal by either party, for delivery to the other party, empty or containing freight solely for such other party, shall be considered delivered with its contents, if any, as soon as it has been placed on said Interchange Tracks, and has passed inspection.

(b) A car brought into said Freight Terminal by either party, containing freight for local delivery, or for transfer, or both, and freight for the other party shall be considered delivered with its contents to such other party as soon as the freight of such party has been removed therefrom.

(c) A car brought into said Freight Terminal by either party, containing freight for local delivery, or for transfer for such party, or both, shall, with its contents, be considered in possession of such party.

(d) An empty car in possession of either party placed in said Freight Terminal for loading and to be forwarded over the lines of the other party shall be considered delivered to such other party as soon as it has been so placed.

(e) Freight in a car brought into said Freight Terminal by either party for transfer to the other party shall be considered delivered as soon as it has been safely loaded into the car in possession of such other party.

(f) Notwithstanding any of the other provisions of this section, in matters of interchange, the American Railway Association's Per Diem Rules and Code of Rules Governing the Condition of, and Repair to, Cars shall apply.

5. The..."A"...Company shall maintain said Freight Terminal and appurtenant facilities in such a manner as may in its judgment be necessary; shall pay all taxes and assessments on said Freight Terminal and appurtenant facilities and premiums on such insurance thereon as may in its judgment be necessary; and shall provide the electrical energy, heat, water, telephone service and other accessories necessary in connection with the operation of said Freight Terminal; provided, however, that the .."B".. Company shall, at its own cost and expense, furnish all special printed forms and stationery it may require for the conduct of its business.

Payments

6. The..."B"...Company shall pay to the..."A"...Company monthly for the privilege of using said Freight Terminal and appurtenant facilities and for the service performed for it by the..."A"...Company, the following sums of money:

FOR GENERAL SUPERVISION OF FREIGHT TERMINAL, USE OF INTERCHANGE TRACKS, INSPECTION OF CARS AND SWITCHING

A proportion of the costs and expenses of the following items to be determined by the ratio of the number of cars switched from and to said Interchange Tracks by the..."B"...Company to the total number of cars switched into and out of said Freight Terminal during such period.

(a) Interest at the rate of....per cent per annum upon the value of said Interchange Tracks including land which for the purpose of this agreement is hereby agreed to be $..............

(b) The sum of $.... per annum representing reserve for retirement of said Interchange Tracks.

(c) Taxes and assessments on said Interchange Tracks.

(d) Expense of maintaining said Interchange Tracks.

(e) The wages paid by the..."A"...Company to the Agents, Yardmasters, Car Foremen, Inspectors, Special Agents and other employees not assigned to but whose services may be wholly or partially required in connection with the work or in the supervision of said Freight Terminal and appurtenant facilities.

(f) The cost of switching including rental of engine, wages of engine and train crews, engine repairs, fuel, water, supplies, engine house expenses and housing of engines.

FOR USE OF FREIGHT STATION

A proportion of the costs and expenses of the following items to be determined by the ratio of the number of tons of L.C.L. freight handled at said Freight Station for account of the..."B"...Company to the total number of tons of L.C.L. freight handled at said Freight Station during such period.

(a) Interest at the rate of .... per cent per annum upon the value of said Freight Station including land which for the purpose of this agreement is hereby agreed to be $..............

(b) The sum of $.... per annum representing reserve for retirement of the several component parts of said Freight Station.

(c) Taxes and assessments and premiums on said insurance on said Freight Station and the cost of electrical energy, heat, water, telephone service and other accessories at said Freight Station.

(d) The expense of maintaining said Freight Station.

(e) The wages paid by the...."A"...Company to the Agent, Clerks, Telegraph Operators, Laborers and other employees engaged at said Freight Station.

For Use of Transfer Platform

A proportion of the costs and expenses of the following items determined by the ratio of the number of tons of L.C.L. freight transferred for the..."B"...Company to the total number of tons of L.C.L. freight transferred at said Transfer Platform during such period.

(a) Interest at the rate of .... per cent per annum upon the value of said Transfer Platform including land which for the purpose of this agreement is hereby agreed to be $..............

(b) The sum of $.... per annum representing reserve for retirement of said Transfer Platform.

(c) Taxes and assessments and premiums on said insurance on said Transfer Platform and the cost of electrical energy, heat, water, telephone service and other accessories at said Transfer Platform.

(d) The expense of maintaining said Transfer Platform.

(e) The wages paid by the..."A"...Company to the Foremen, Laborers, Clerks and other employees engaged in connection with transferring L.C.L. freight at said Transfer Platform.

For Use of Team Track Yard

A proportion of the costs and expenses of the following items determined by the ratio of the number of cars inbound and outbound handled for account of the ..."B"...Company to the total number of cars inbound and outbound handled in said Team Track Yard.

(a) Interest at the rate of .... per cent per annum upon the value of said Team Track Yard including land during such period which for the purpose of this agreement is hereby agreed to be $..............

(b) The sum of $.... per annum representing reserve for retirement of said Team Track Yard.

(c) Taxes and assessments on said Team Track Yard and premiums on said insurance on said Team Track Yard Office and the cost of electrical energy, heat, water, telephone service and other accessories in connection with said Team Track Yard.

(d) The expense of maintaining said Team Track Yard.

(e) The wages paid by the..."A"...Company to the Clerks, and other employees engaged at said Team Track Yard.

For Use of Icing Station

A proportion of the costs and expenses of the following items determined by the ratio of the number of tons of ice furnished to cars for account of the..."B"...Company to the total number of tons of ice furnished to all cars from said Icing Station during such period.

(a) Interest at the rate of .... per cent per annum upon the value of said Icing Station including land which for the purpose of this agreement is hereby agreed to be $..............

(b) The sum of $..... per annum representing reserve for retirement of said Icing Station.

(c) Taxes and assessments and premiums on said insurance on said Icing Station, and the cost of electrical energy, heat, water, telephone service and other accessories at said Icing Station.

(d) The expense of maintaining and operating said Icing Station.

(e) The wages paid by the..."A"...Company to the Foremen, Clerks, Laborers and other employees engaged at said Icing Station.

Bills rendered hereunder will include 10 per cent overhead charge on labor for supervision, transportation, accounting and similar items and 15 per cent overhead charge on materials for supervision, storehouse expense, transportation, accounting and similar items.

Bills are to be rendered monthly on or before the .... day of each month and shall be paid within .... days thereafter, and no bill shall remain unpaid for a longer period than .... days, but it is agreed that if any items in said bills are not agreed to at the time paid they may be later adjusted but no account or bill shall be open for adjustment after it has been closed or paid for twelve months.

The..."B"...Company shall have the right to inspect the records and accounts of the..."A"...Company relating to the operation of said Freight Terminal at all reasonable times.

Additions and Betterments

7. In the event that any additions to, or betterments or improvements of, the facilities of the..."A"...Company to be jointly used by the..."B"... Company hereunder shall, at any time hereafter and during the life of this agreement, in the judgment of the..."A"...Company, be deemed to be necessary for the joint use of the parties hereto, then and in such event, the..."A"...Company may, in its discretion and without the concurrence of the..."B"...Company, make and construct the same, and thereafter the..."B"...Company shall pay additional interest at the rate hereinbefore provided on the cost of said additions and betterments as charged to the..."A"...Company's capital account in accordance with the rules of the Interstate Commerce Commission and shall also pay a proportion of the cost of maintenance and operation of the same as hereinbefore provided.

Custody of Property

8. All cars of the..."B"...Company and the contents thereof, while upon the said tracks of the ..."A"... Company, as well as all freight held by or for account of the..."B"...Company in, upon or about the said Freight House, Platform or other Terminal facilities of the..."A"...

Company so as to be jointly used hereunder, as aforesaid, shall, for the purpose of this agreement, be deemed and considered to be under the control and in the custody and care of the..."B"...Company and the..."B"... Company shall carry its own fire insurance upon same.

9. The..."A"...Company shall provide for the movement of the freight cars of the..."B"...Company over its tracks as nearly as may be practicable in accordance with the request of the..."B"...Company, and shall exercise in the handling of such cars the same degree of care that it exercises in the handling of its own cars.

10. In case the..."B"...Company shall by reason of strike, riot, insurrections, civil or military authority, fire, explosion, Act of God or any other unavoidable casualty be deprived of the use of said facilities or any part thereof, a reduction of said rental shall be made to it for the time during which said deprivation shall continue, proportionate to the amount of said deprivation.

11. All employees of the..."A"...Company in said Freight Terminal hereinbefore provided for shall for the purpose of this agreement, be considered to be sole employees, in the performance of, or omission to perform, services, the benefit or other result of which accrues to either party hereto, solely; and as joint employees, in the performance of, or omission to perform, services, the benefit or other result of which accrues to both parties hereto jointly.

Liability

12. Liability for all loss of or damage to property and injury to or death of persons (all hereinafter collectively referred to as damage), in any manner originating or occurring upon or in connection with the operation of the property and facilities covered by this agreement, and upon or in connection with any use made by the..."B"...Company of tracks and facilities of the..."A"...Company as access thereto, shall be governed by the following provisions:

Each party hereto shall be liable for all damage which shall be caused in any manner by or in connection with its business or traffic, when the business or traffic of the other party is in no wise involved.

Each party hereto shall be liable for all damage which shall be caused solely:

(a) By defect in its sole property or property separately used by it.

(b) By act or by the negligence of its separate employees.

Otherwise, each party shall be liable for all damage to its separate property, employees or traffic.

All other damages and costs and expenses in connection therewith, including those resulting from undetermined causes, shall be borne equally by the parties hereto.

Each party shall adjust the claims of its own employees. No settlement for which the other party is to be held wholly responsible, and no settlement in excess of Five Hundred Dollars ($500.00) for which the other party is to be held jointly responsible, shall be made without its concurrence.

In event of any suit being brought against either party hereto, for which the other party may be held liable, the party against whom such suit is brought shall at once give the other party notice in writing thereof in order that the other party may make such defense as it may deem proper, and in such case the party that is liable as herein provided shall pay all attorneys' fees, costs and expenses incurred in defending such suit, as well as damages that may be recovered therein.

Default

13. If the..."B"...Company shall make default in any of the payments hereinbefore required of it to be made, or shall fail to faithfully perform any of the covenants herein required by it to be performed, then in such case, and if such default or failure shall continue for a period of .... (....) days after the ..."A"...Company shall have given the..."B"...Company a written notice thereof, the..."A"...Company may, by a .... (....) days notice in writing to the ..."B"... Company, declare this agreement terminated, and may at the termination of the said .... (....) days in said notice mentioned, exclude the..."B"... Company from the use and enjoyment of any and all of the premises and privileges hereunder and the..."B"...Company shall discontinue the use of all of said premises and privileges and shall have no claim or demand upon it by suit at law or otherwise, on account of such exclusion, provided, that failure to make any payment or perform any covenant which is the subject of arbitration or of litigation between the parties hereto, shall not, pending arbitration or litigation, be deemed a cause of forfeiture hereunder.

The..."A"...Company may waive any such default or failure, but no action of the..."A"...Company in waiving such default or failure shall extend to, or be taken to affect any subsequent default or failure, or impair its rights.

Arbitration

14. In case any question arises under this agreement or concerning the subject matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole disinterested arbitrator, to be selected jointly by the parties to this agreement.

The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as may be determined by the arbitrator.

Term

15. This agreement shall take effect on the .... day of ...., 19.... and, unless earlier terminated as hereinbefore prescribed, shall continue in force for the period of .... years from said date and thereafter until terminated on a date specified by a written notice given to either party by the other party at least .... prior to such date of termination.

This agreement shall inure to the benefit of and be binding upon the parties hereto, their successors and assigns, but no transfer or assignment shall be made by the..."B"...Company without the prior written consent of the..."A"...Company.

IN WITNESS WHEREOF, the parties hereto have executed this agreement the day and year herein first above written.

....

Company.

By ....

President.

Attest:

....

Secretary.

....

Company.

By ....

President.

Attest:

....

Secretary.

NOTE:—In event the..."A"...Company shall permit any other railway company or companies to use said Freight Terminal and appurtenant facilities, then the proportion of liability under Section 12 assumed by the ..."B"...Company shall be determined by the ratio of one to the total number of companies using the Freight Terminal and appurtenant facilities.

[19]FORM OF COST-PLUS PERCENTAGE CONSTRUCTION CONTRACT

THIS CONTRACT, made this .... day of .... in the year ...., by and between .... hereinafter called the Contractor, and .... hereinafter called the Company.

WITNESSETH, That, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto, and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

The Contractor shall furnish all of the materials, superintendence, labor, tools, equipment and transportation, except as hereinafter specified, and shall execute, construct and finish, in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Company, all of the work required for ....
....
....
....
....
in accordance with the plans furnished or to be furnished during the progress of the work and identified by the signature of the Engineer, together with the specifications hereby included and the instructions hereafter to be given by the Engineer.

The work covered by this contract shall be commenced on or before the .... day of ...., 19......, and shall be completed on or before the .... day of ...., 19......

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[19] Adopted, Vol. 30, 1929, pp. 325, 1373.

And in consideration of the completion of the work described herein and the fulfillment of all stipulations of this contract to the satisfaction and acceptance of the Chief Engineer of the Company, the Company shall pay, or cause to be paid, to the Contractor, the amount due to the Contractor based on the cost hereinafter defined, plus the fee hereinafter specified.

1. Intent of Plans and Specifications

All work that may be called for in the specifications and not shown on the plans, or shown on the plans and not called for in the specifications, shall be executed and furnished by the Contractor as if described in both these ways; and should any work or material be required which is not detailed in the specifications or on the plans, either directly or indirectly, but which is nevertheless necessary for the proper carrying out of the intent thereof, the Contractor is to understand the same to be implied and required, and shall perform all such work and furnish any such material as fully as if they were particularly detailed or described.

2. Contractor's Understanding

It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all other matters which can in any way affect the work under this contract. No verbal agreement or conversation with any officer, agent or employee of the Company, either before or after the execution of this contract, shall affect or modify any of the terms or obligations herein contained.

3. Land for Use of Contractor

The Company shall provide the land upon which the work under this contract is to be done, and will, so far as it can conveniently do so, permit the Contractor to use so much of its land as is required for temporary construction purposes and the storage of materials, together with the right of access to same, and in addition thereto, such lands not owned by the Company as may be, in the opinion of the Engineer, necessary for such purposes.

4. Consent to Transfer

The Contractor shall not let or transfer this contract or any part thereof (except for the furnishing and delivery of material) without consent of the Chief Engineer, given in writing. Such consent does not release or relieve the Contractor from any of his obligations and liabilities under the contract.

5. Sub-Contractor

The Contractor shall procure and submit to the Chief Engineer competitive proposals, from sub-contractors satisfactory to the Engineer, for items of work to be sub-contracted. From these proposals the Chief Engineer shall select the sub-contractors to perform the work.

The Contractor shall enter into a contract with each sub-contractor so selected in a form satisfactory to the Chief Engineer.

Sub-contractors shall deal directly with the Contractor who shall be responsible for the execution of the work in accordance with the terms of this contract.

6. Engineer and Chief Engineer

Wherever in this contract the word Engineer is used, it shall be understood as referring to the Chief Engineer of the Company, acting personally or through an assistant duly authorized in writing for such act by the Chief Engineer, and wherever the words Chief Engineer are used it shall be understood as referring to the Chief Engineer in person, and not to any assistant engineer.

7. Power of Engineer

The Engineer shall have power to reject or condemn all work or material which does not conform to this contract; to direct the application of forces to any portion of the work which, in his judgment, requires it; to order the force increased or diminished, and to decide questions which arise between the parties relative to the execution of the work.

8. Waiver

It is expressly understood and agreed that any waiver on the part of the Company or the Engineer, of any term, provision or covenant of this contract, shall not constitute a precedent, nor bind the Company or the Engineer, to any further waiver of the terms, provisions or covenants of this contract.

9. Adjustment of Dispute

All questions or controversies which may arise between the Contractor and the Company, under or in reference to this contract, shall be subject to the decision of the Chief Engineer, and his decision shall be final and conclusive upon both parties.

10. Permits

Permits of a temporary nature necessary for the prosecution of the work shall be secured and paid for by the Contractor as a part of the cost of the work.

Permits for permanent structures or permanent changes in existing facilities shall be secured and paid for by the Company, on which expense the Contractor shall receive no fee.

11. Insurance

The Contractor shall secure in the name of the Company, policies of insurance in amount, form and companies, satisfactory to the Chief Engineer, upon such structures and material as shall be specified by the latter, payable to the Company for the benefit of the Contractor or the Company as the Chief Engineer shall find their interests to appear.

12. Workmen's Compensation Insurance

The Contractor shall comply with all the laws of the State wherein the contract is to be performed, arising under any "Workmen's Compensation Act," and shall at all times carry and pay the premiums on all policies of insurance required by the laws of the State wherein the work is being performed, under any "Workmen's Compensation Act," so that the Company shall be fully protected from any and all claims for damages for personal injury, including death, which may arise from operations under this contract, whether such operations be by himself, or by any subcontractor, or anyone directly or indirectly employed by either of them. Certificates of such insurance shall be filed with the Chief Engineer, if he so requires, and shall be subject to his approval for adequacy of protection.

13. Indemnity

The Contractor shall furnish indemnity insurance in amount, form and substance satisfactory and acceptable to the Company, which insurance shall indemnify and save harmless the Company from and against all losses and all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description made, brought or recovered against the Company by reason of any act or omission of the Contractor, his agents or employees, in the execution of the work, or in guarding the same.

14. Superintendence

The Contractor shall constantly superintend all of the work embraced in this contract, in person or by a duly authorized representative acceptable to the Company.

15. Notice—How Served

Any notice to be given by the Company to the Contractor under this contract shall be deemed to be served if the same be delivered to the person in charge of the office used by the Contractor, or to his representative at or near the work, or deposited in the postoffice, postpaid, addressed to the Contractor at his last known place of business.

16. Protection

The Contractor shall furnish and maintain passageways, guard fences and lights and such other means of protection to persons and property as may be necessary or required by local conditions, laws or ordinances.

17. Timely Demand for Points and Instructions

The Contractor shall provide reasonable and necessary opportunities and facilities for setting points and making measurements. He shall not proceed until he has made timely demand upon the Engineer for, and has received from him, such points and instructions as may be necessary as the work progresses. The work shall be done in strict conformity with such points and instructions.

18. Preservation of Stakes

The Contractor shall carefully preserve bench marks, reference points and stakes, and in case of wilful or careless destruction, he will be charged with the resulting expense and shall be responsible for any mistakes that may be caused by their unnecessary loss or disturbance.

19. Report Errors and Discrepancies

If the Contractor, in the course of the work, finds any discrepancy between the plans and the physical conditions of the locality, or any errors or omissions in plans or in the layout as given by points and instructions, it shall be his duty to immediately inform the Engineer, in writing, and the Engineer shall promptly verify the same.

20. Inspection

All work and material shall be at all times open to the inspection, acceptance or rejection of the Engineer or his authorized representative. The Contractor shall give the Engineer reasonable notice of starting any new work and shall provide reasonable and necessary facilities for inspection even to the extent of taking out portions of finished work. No work shall be done at night without the previous approval of the Engineer.

21. Tests of Materials

The Contractor shall furnish, if requested by the Engineer, samples of any materials to be used in the work, for such tests as may be desired; the materials thereafter furnished shall be in strict accordance with approved samples.

22. Fitness, Condition and Value of Plant

The tools and equipment furnished by the Contractor shall be in a first class workable condition when received on the work and shall be subject to the approval of the Engineer as to their fitness and condition for the work to be performed.

The Chief Engineer shall, at the time of receipt, fix a fair valuation for each of such tools and equipment.

23. Rentals

The rentals of tools and equipment, not purchased for the work, and not including hand tools owned by the workmen, shall be in accordance with the schedule of tools and equipment and rates hereto attached and made a part of this contract. The period of rental for any article shall extend from the date it is placed in operation on the work, and shall be continuous, including Sundays and holidays, until such time as the Engineer shall notify the Contractor, in writing, that it is no longer needed.

24. Purchase of Material

The Contractor shall prepare necessary bills of materials required for the work and shall make purchases and contracts in his own name. Purchases exceeding .... Dollars in cost shall be purchased from the lowest bid submitted by not less than three reputable dealers, provided that under such bid the materials of quantity required and quality specified can be furnished without delay to the Contractor.

The Contractor shall, before purchasing, tabulate and submit such bids to the Chief Engineer, with recommendation for approval.

The Chief Engineer, if he so desires, may secure bids for materials, and such bids shall be given the same consideration as if secured by the Contractor.

25. Routing Shipments

All shipments in connection with this contract shall be routed as may be directed by the Company.

26. Work Adjacent to Railway or Other Property

Wherever the work embraced in this contract is near the tracks, structures or buildings of the Company or of other railways, or persons, the Contractor shall use proper care and vigilance to avoid injury to persons or property. The work shall be so conducted as not to interfere with the movement of trains or other operations of the railway; or, if in any case such interference be necessary, the Contractor shall not proceed until he has first obtained specific authority and directions therefor from the proper designated officer of the Company and has the approval of the Engineer.

27. Rights of Various Interests

Wherever work being done by Company forces or by other contractors is contiguous to work covered by this contract, the respective rights of the various interests involved shall be established by the Engineer, to secure the completion of the various portions of the work in general harmony.

28. Order and Discipline

The Contractor shall at all times enforce strict discipline and good order among his employees, and any employee of the Contractor who shall appear to be incompetent, disorderly or intemperate, or in any other way disqualified for or unfaithful to the work entrusted to him, shall be discharged immediately on the request of the Engineer, and he shall not again be employed on the work without the Engineer's written consent.

29. Contractor Not to Hire Company's Employees

The Contractor shall not employ or hire any of the Company's employees without the permission of the Engineer.

30. Order of Completion—Use of Completed Portions

The Contractor shall complete any portion or portions of the work in such order of time as the Engineer may require. The Company shall have the right to take possession of and use any completed or partially completed portions of the work, notwithstanding the time for completing the entire work or such portions may not have expired; but such taking possession and use shall not be deemed an acceptance of the work so taken or used or any part thereof.

31. Changes

The Company shall have the right to make any changes that may be hereafter determined upon, in the nature or dimensions of the work, either before or after its commencement, and such changes shall in no way affect or void the obligations of this contract, nor shall such changes constitute a claim for damages or for anticipated profits.

32. Unavoidable Delays—Extension of Time on Parts of Work

If the Contractor shall be delayed in the performance of the work from any cause beyond his control, he may, upon written application to the Chief Engineer within three (3) days of such delay, be granted such extension of time as the Chief Engineer shall deem equitable and just.

33. Suspension of Work

The Company may at any time stop the work or any part thereof by giving .... days notice, in writing, to the Contractor. The work shall be resumed by the Contractor within ten (10) days after the date fixed in a written notice from the Company to the Contractor so to do. The Company will pay the Contractor for the expense of men and equipment necessarily retained during the interval of suspension; provided, the Contractor can show that it was not reasonably practicable to move the men and equipment to other points at which they could have been employed. If the Company does not give notice in writing to the Contractor to resume work at a date within .... days of the date fixed in the written notice to suspend, then the Contractor may abandon that portion of the work so suspended and he will be entitled to payment, under the terms of this contract, for work done on such portion so abandoned.

34. Annulment Without Fault of Contractor

The Company shall have the right at any time, for reasons which appear good to it, to annul this contract upon giving notice, in writing, to the Contractor, in which event the Contractor shall be entitled to payment, under the terms of this contract, for work done up to the time of such annulment, together with the actual cost to the Contractor of relief from liability with respect to commitments actually entered into prior to date of notice of such annulment. The Contractor shall make no voluntary settlement with any party to whom commitment is due without the approval of the Chief Engineer.

The Contractor shall make no claim for damages of any kind or for fee or anticipated profits upon work not actually performed.

35. Failure of Performance by Contractor

(a) If the Chief Engineer of the Company shall at any time be of the opinion that the Contractor is not progressing with the work as fast as necessary to insure its completion within the time and as required by the contract, or is otherwise violating any of the provisions of this contract, the Chief Engineer, in behalf of the Company, shall have the power, and it shall be his duty, to notify the Contractor in writing to proceed more rapidly with the work, or otherwise to comply with the provisions of this contract.

(b) If on the expiration of ten (10) days after the serving of such written notice upon the Contractor, the Contractor shall continue to neglect the work and shall fail to satisfy the Engineer of his efforts, ability and intentions to remedy the specified deficiencies, the Company may terminate the employment of the Contractor or may take possession of any part of the work and of all materials, tools and equipment thereon, and employ such means as, in the Engineer's judgment, may be necessary to finish the work. In this case the Contractor shall be paid for the work done by him. If the Company should utilize the tools and equipment of the Contractor for the completion of the work, the Contractor shall be paid the rental charges as provided under this contract.

36. Removal of Equipment

In case of annulment of this contract before completion from any cause whatever, the Contractor, if notified to do so by the Company, shall promptly remove any part or all of his tools and equipment from the property of the Company, failing which the Company shall have the right to move such tools and equipment.

37. Settlement for Wages

Whenever, in the opinion of the Chief Engineer, it may be necessary for the progress of the work to secure to any of the employees engaged on the work under this contract any wages which may then be due them, the Company is hereby authorized to pay said employees the amount due them or any lesser amount, and the amount so paid them, as shown by their receipts, shall be deducted from any moneys that may be or become payable to the Contractor.

38. Accounts and Records

The Contractor shall keep accurate and detailed accounts of all disbursements in form satisfactory to the Chief Engineer, and shall give the Engineer access at any or all times to the Contractor's books appertaining to such disbursements. If the Chief Engineer desires, he shall have the right to place competent employees in any position of accounting or checking, in which event such employees shall perform their respective duties in accordance with the method for handling the work adopted by the Contractor.

39. Costs to Which the Fee to the Contractor Shall Be Added

(a) LABOR.—The labor cost shall be the actual payroll costs for all fieldmen or temporary field office force employed by the Contractor in connection with and at the work. It shall include the cost of loading tools and equipment, for shipment to the site of the work and unloading at the site, and the cost, upon completion of the work, of loading the same for shipment, and unloading at the Contractor's store yard or other approved destination. The rates paid shall not be higher than the standard rates paid for similar service in the locality of the work, without the prior written approval of the Chief Engineer.

The labor cost shall not include any part of the Contractor's general expenses or the salaries of his officers, or of office employees who do not devote their entire time to the work covered by this contract, unless specifically authorized by the Chief Engineer.

(b) MATERIALS.—The material cost shall be the actual costs to the Contractor of materials entering into the work covered by this contract, as evidenced by the correct receipted bills rendered by the dealer to the Contractor and approved by the Engineer.

Any trade discount, rebate or commission granted to the Contractor or any employees shall be credited to the cost, except that cash discounts for prompt payments are for the benefit of the Contractor.

The cost of materials and tools properly purchased for the work but not actually incorporated therein shall be the net first cost as above defined less the sale price or market value at the termination of the work, as approved by the Engineer.

(c) SUB-CONTRACTS.—The cost of sub-contracts shall be the actual cost shown by original bills and payrolls, rendered by the Sub-Contractor to the Contractor and approved by the Engineer.

(d) RUNNING REPAIRS TO PLANT.—The cost of running repairs shall be the material and labor costs.

(e) TRANSPORTATION.—The cost of transportation shall include the costs to the Contractor of transportation of materials over lines other than that of the Company and of labor properly brought from a distance with the approval of the Engineer, together with the necessary traveling expenses properly incurred, in connection with the work, and paid by the Contractor.

(f) BONDS AND INSURANCE.—The cost of premiums on bonds and insurance required, if paid by the Contractor.

(g) TELEGRAPH AND TELEPHONE SERVICE.—The cost of telegraph and telephone service connected with the work, if paid by the Contractor.

(h) PERMITS.—The cost of permits secured and paid for by the Contractor.

40. Costs to Which the Fee to the Contractor Shall Not Be Added

(a) TRANSPORTATION.—Transportation charges on tools and equipment of the Contractor to the site of the work and return from the site of the work to the store yard of the Contractor or other agreed destination. Tranpsoration charges over the lines of the Company.

(b) DEMURRAGE.—Demurrage on cars.

(c) WORK TRAIN.—The cost of work train service furnished by the Company.

(d) WATCHMEN.—The cost of watchmen and flagmen furnished by the Company.

(e) PLANT RENTAL.—Fixed prices for rental of tools and equipment.

41. Service to Be Furnished by the Contractor, the Cost of Which Is Paid for in the Fee to the Contractor

(a) The services of the Contractor's executive officers, who shall direct and oversee the work.

(b) The services of the Contractor's Purchasing Department, which shall make all major purchases.

(c) The services of the Contractor's employment and personnel departments, who will supervise the labor conditions pertaining to the work.

(d) The services of the Contractor's home office accounting and cost accounting department, which will establish proper systems of accounting for the work and accumulate the detail figures for final vouchering and reporting under the rules of the Interstate Commerce Commission.

(e) All general expenses of the Contractor's general offices, which shall include rent, light, heat, postage, service of stenographers, clerks and like costs.

(f) In general, all items which constitute overhead costs of the Contractor and which items are not properly a part of .the direct costs of the work.

42. Fee (Percentage)

The Contractor shall be paid in addition to the cost of the work as herein defined .... per cent of such cost, as his fee for services rendered.

43. Failure to Make Payments

Failure by the Company to make payments at the times provided in this contract, shall give the Contractor the right to suspend work until payment is made; or at his option, after .... days notice in writing, should the Company continue to default, to terminate this contract and recover the cost of all work done and materials provided. The Company's failure to make payments at the times provided shall be a bar to any claim by the Company against the Contractor for delay in completion of the work, due to such suspension for failure to pay.

44. Payments

Between the first and seventh of each month the Contractor shall present to the Chief Engineer a statement of the cost of the work for the preceding month with such payrolls, receipts and vouchers as the Chief Engineer may require, together with a statement of moneys due and unpaid in connection with the contract. The Chief Engineer shall promptly check the statement of the costs, including the rental of tools and equipment for the period covered by the statement and the correct amount due together with the fee earned shall be paid to the Contractor by the Company, on or about the .... of the current month.

Upon the completion and acceptance of the work, and satisfactory evidence of the payment by the Contractor of all obligations accruing under the contract for which the Company may be legally liable, the Chief Engineer shall promptly certify the final amount due, including the fee provided under this contract, and payment shall be made by the Company to the Contractor within thirty (30) days after the date of the Chief Engineer's certificate, giving the final amount due.

This contract shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

In Witness Whereof, the parties hereto have executed this contract, in ...., the day and year first above written.

....

(Contractor)

Witness:

.... By............................

....

(Company)

Attest:

.... By............................

See Bulletin adopted July 1921

COMMITTEE XXI

ECONOMICS OF RAILWAY OPERATION

[1]A FORMULA OR METHOD OF CALCULATING THE COST OF MOVING FREIGHT TRAFFIC

The method is designated to include Maintenance of Way, Maintenance of Equipment, Transportation, Traffic, General Expenses and Fixed Charges that enter into and should be applied in determining the cost of the movement of freight between any two points on the railroad or through or over any special facility operated by the Railroad Company incident to performing its function of manufacturing transportation.

The accuracy of the results that may be desired is only limited by the degree of refinement that may be practical in developing the various tables to be used in the application of the formula in solving the many problems of operating costs that are constantly coming before railroad managers. As an illustration, it may be desired to know the cost of handling live stock from a midwestern point to a market center or to tidewater, or the cost of handling grain or other individual commodity or miscellaneous freight between certain points on the line. The formula will also be useful in comparing the cost of moving a given volume of traffic via two different routes. Certain important interests may offer a large additional tonnage for transportation between two points and by the application of this formula it may quickly be determined whether or not this additional business would be profitable.

In presenting the tables the spread, or period of time, the figures cover is not indicated; this must necessarily be left to the individual carrier, as conditions will vary greatly on different railroads. In the case of wages, fuel and other supplies, the latest prices would ordinarily be best. The same thought may apply to most all items in the Maintenance of Way and Maintenance of Equipment Accounts, except items of repair, where a greater spread should be used in order to take into account seasonal variation in business and expense. Where wages are spread over a long period involving a change in rate of pay, the same should be equated to present-day basis.

Direct and indirect expense items are developed in certain tables: In the Maintenance of Way and Maintenance of Equipment Accounts the indirect expense is based on the ratio of dollars expended per dollar of direct expense and in the case of transportation accounts the indirect expense is based on the ratio of dollars expended per train mile. In other words, the indirect expense is based on the ratio of expense not affected by use or volume of business handled to expense which is affected by use or the volume of business handled. This method is adapted to problems not involving increases or decreases in traffic; however, should the problem involve a change in the volume of business, it will be necessary to equate the indirect expense units inversely to such variation in the traffic to be handled.

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[1] Adopted, Vol. 25, 1924, pp. 714, 1316.

The same consideration should be made in applying the unit costs for fixed charges, which, within certain limits, will increase as the volume of business decreases and decrease as the volume of business increases.

The figures set up in the various tables are of value only in illustrating a plan by which this method or formula may be worked out. Tables of similar units can be set up in forms very concise and convenient for ready reference in applying this method to the problems to be met with on the several operating divisions of a railroad.

North and South Railroad

A FORMULA FOR ESTIMATING THE COST OF MOVING FREIGHT TRAFFIC—DERIVATION OF COST DATA

Table 1 Engine and Train Crew Wages in Through and Local Freight Service.	This table is compiled from data furnished by the Bureau of Rates of Pay. The figures should be based on the current rates of pay in effect. Straight pay per eight hour day (or per 100 miles), and hourly overtime rate of entire crew (engineman, fireman, conductor, flagman, and one, two or three brakemen, as conditions may require), are given for each class of power and kind of service.
Table 2 Rates of Pay for Enginemen, Firemen, Trainmen and Yardmen.	This table is prepared from the same information used in compiling Table 1, and is intended to supply the necessary detail for modifying total crew pay where special operating conditions exist, such as the use of two road engines per train, or other features not covered by the standard crew combinations given in Table 1.
Table 3 **Column 1** Direct Expense—Fuel Hauling and Handling per ton.	This item covers Direct Freight Transportation and Maintenance of Equipment Expense per ton for hauling Company coal from mine to fuel station, plus cost per ton for fuel station operation. In computing the cost of haul from the originating point to any given division, the first step is to obtain the average direct expense per net ton mile of all freight, on each division participating in the movement. The average length of total haul of fuel, to the given division, is then obtained from the Fuel Bureau, or other source, and each participating division is assigned its portion of this mileage.

The average net ton mile cost (direct expense) on each division affected is multiplied by its assigned portion of the entire haul, and by totaling these products the cost of haul per ton is determined for the entire distance.

The cost per ton for fuel station operation is obtained for each division by dividing Account 394-c by the total tons of passenger and freight fuel disbursed.

Table 3
Column 2

Direct Expense—Water per 1,000 Gallons.

This cost is obtained by converting total passenger, freight and yard fuel disbursed on each division, into equivalent gallons of water, on the basis of one gallon of water for each pound of coal, and dividing Accounts 385 and 397—the divisional water expense—by the equivalent gallons so obtained.

Table 3
Column 3

Direct Expense—Station Agents, Clerks and Supplies per Train Mile.

This item includes the total freight portions of Accounts 373 and 376 less the labor Sub-accounts 373-d and 373-e. The figures in Column 3 are obtained by dividing these net amounts by the freight train mileage.

Table 3
Column 4

Direct Maintenance of Way Expenses (Roadway and Track) per 1,000 Gross Ton Miles.

This expense includes all Maintenance of Way and Structure items considered as being affected by use or volume of traffic.

The accounts, listed in detail, as developed by Sub-Committee No. 6 of Committee No. XXI (See Appendix F, Vol. 24, Proceedings, 1923, pages 1084 to 1094, inclusive), are shown in the following Table A, the freight portion only being used. Separation between Passenger and Freight expenses is made according to the Interstate Commerce Commission formula "Rules governing the separation of Operating Expenses between freight service and passenger service on large steam railways, effective January first, 1920." This method of separating passenger and freight expenses may be revised to meet the needs of the individual carrier.

TABLE A

Maintenance of Way and Structure Accounts	1 Acct. No.	2 Per Cent of Total M.W.&S. Expense	3 Per Cent Affected by Use	4 Per Cent Not Affected by Use	5 (Direct Expense) Per Cent Total M. W. & S. Expense Affected by Use	6 (Indirect Expense) Per Cent Total M. W. & S. Expense Not Affected by Use
Ties	212	15.41	30	70	4.62	10.79
Rails	214	2.99	100	....	2.99	....
Other Track Material	216	4.52	100	....	4.52	....
Ballast	218	1.88	80	20	1.50	.38
Superintendence	201	5.69	20	80	1.14	4.55
Roadway Maintenance	202	10.96	....	100	....	10.96
Tracklaying and Surfacing	220	25.91	55	45	14.25	11.66
Roadway—Fences	221	.87	....	100	....	.87
Snow, Sand Fences, Etc.	223	.11	....	100	....	.11
Crossings and Signs	225	1.30	....	100	....	1.30
Roadway Machines	269	.45	....	100	....	.45
Small Tools and Supplies	271	1.13	40	60	.45	.68
Removing Snow, Ice, Etc.	272	1.76	....	100	....	1.76
Bridges, Terminals and Culverts	208	7.38	10	90	.74	6.64
Tunnels and Subways	206	.32	10	90	.03	.29
Elevated Structures	210	.01	....	100	....	.01
Station and Office Buildings	227	3.93	....	100	....	3.93
Roadway Buildings	229	.53	....	100	....	.53
Water Stations	231	1.31	10	90	.13	1.18
Fuel Stations	233	.53	15	85	.08	.45
Shops, Engine Houses	235	2.45	10	90	.25	2.20
Grain Elevators	237	.06	....	100	....	.06
Storage Warehouses	239	.01	....	100	....	.01
Wharves and Docks	241	.61	10	90	.06	.55
Coal and Ore Wharves	243	.55	10	90	.06	.49
Gas Power Plants	245	.01	....	100	....	.01
Power Plant Buildings	253	.07	....	100	....	.07
Power Substation Buildings	255	.01	....	100	....	.01
Miscellaneous Structures	265	.09	....	100	....	.09
Underground Power Tube	204	#	....	100	....	....
Power Plant, Dams and Pipe Lines	251	#	....	100	....	....
Power Transportation System	257	.03	....	100	....	.03
Power Distributing System	259	.25	....	100	....	.25
Power Line Poles and Fixtures	261	.03	....	100	....	.03
Underground Conduits	263	....	....	100	....	....
Telegraph and Telephone Lines	247	1.11	....	100	....	1.11
Signals and Interlockers	249	2.67	30	70	.80	1.87
Shop Machinery	302	2.78	40	60	1.10	1.66
Power Plant Machinery	304	.44	5	95	.02	.42
Power Substation Apparatus	306	.03	....	100	....	.03
Paving	267	.05	....	100	....	.05
Assessments, Public Improvements	273	.07	....	100	....	.07
Injuries to Persons	274	.73	50	50	.37	.37
Insurance	275	.61	....	100	....	.61
Stationery and Printing	276	.20	10	90	.02	.18
Other Expenses	277	.17	....	100	....	.17
Totals		100.00			33.13	66.87

#Less than .01 per cent.

The unit values given in Table 3, Column 4, are obtained by dividing the total expense (freight) for the above items, by the gross ton mileage made on each division.

It may be found expedient to handle certain special facilities separately, as Coal and Ore Wharves Account 243 and Grain Elevators Account 237, in which event they may be taken out of Table A, and treated as indicated and shown in Table 3-C.

Table 3
Column 5

Indirect Transportation Expense per Train Mile.

The following items of Freight Transportation Expenses are covered by this heading:

371—Superintendence.
372—Dispatching Trains.
374—Weighing, Inspection and Demurrage Bureaus.
377—Yard Masters and Yard Clerks.
379—Yard Switch and Signal Tenders.
389—Yard Supplies and Expenses.
390—Operation Joint Yards and Terminals.—Dr.
391—Operation Joint Yards and Terminals.—Cr.
404—Signals and Interlocking Operation.
405—Crossing Protection.
406—Drawbridge Operation.
407—Telegraph and Telephone Operation.
410—Stationery and Printing.
411—Other Expenses.
412—Operation Joint Tracks and Facilities—Dr.
413—Operation Joint Tracks and Facilities.—Cr.
414—Insurance.
415—Clearing Wrecks.
416—Damage to Property.
417—Damage to Livestock on Right-of-Way.
418—Loss and Damage—Freight.
420—Injuries to Persons.

The unit values given in Column 5 are obtained by dividing the total expenses (freight) for the above items, by the freight train mileage made on each division.

Table 3
Column 6

Indirect Maintenance of Equipment Expense per Dollar of Direct Maintenance of Equipment Expense.

The total direct expense and total indirect expense on each division is obtained by applying the percentages shown in the following Table B, Columns 5 and 6, using freight portion only. The unit values in Table 3, Column 6, are obtained by dividing the indirect expense by the corresponding direct expense.

The percentages in Table B have been determined by using the best information developed for the test period (1915-1916-1917) collaborating with experienced mechanical engineers.

It will be noted that 56.89 per cent of the maintenance of equipment expense is direct or may vary with the business handled and 43.11 per cent is indirect or may not be affected with the business handled.

TABLE B

Maintenance of Equipment Accounts	1 Account No.	2 Per Cent of Total M. of E. Expense	3 Per Cent Affected by Use	4 Per Cent Not Affected by Use	5 Direct Expense Per Cent of Total M. of E. Expense Affected by Use	6 Indirect Expense Per Cent of Total M. of E. Expense Not Affected by Use
Superintendence	301	3.34	10	90	.33	3.01
Shop Machinery	302	1.97	40	60	.79	1.18
Shop Machinery Depreciation	303	......	......	......	....	....
Power Plant Machinery	304	.22	5	95	.01	.21
Power Plant Machinery Depreciation	305	......	......	......	....	....
Power Substation Apparatus	306	.01	......	100	....	.01
Power Substation Apparatus Depreciation	307	......	......	......	....	....
Steam Locomotive Repairs	308	40.85	86	14	35.13	5.72
Steam Locomotive Depreciation	309	4.72	......	100	....	4.72
Steam Locomotive Retirements	310	.24	......	100	....	.24
Other Locomotive Repairs	311	.05	75	25	.04	.01
Other Locomotive Depreciation	312	.03	......	100	....	.03
Other Locomotive Retirements	313	.03	......	100	....	.03
Freight Train Cars—Repairs	314	25.49	65	35	16.57	8.92
Freight Train Cars—Depreciation	315	8.82	......	100	....	8.82
Freight Train Cars—Retirements	316	5.07	......	100	....	5.07
Passenger Train Cars—Repairs	317	3.63	76	24	2.76	.87
Passenger Train Cars—Depreciation	318	.79	......	100	....	.79
Passenger Train Cars—Retirements	319	.13	......	100	....	.13
Motor Equipment of Cars—Repairs	320	......	75	25	....	....
Motor Equipment of Cars—Depreciation	321	......	......	100	....	....
Motor Equipment of Cars—Retirements	322	......	......	100	....	....
Floating Equipment—Repairs	323	1.42	10	90	.14	1.28
Floating Equipment—Depreciation	324	.18	......	100	....	.18
Floating Equipment—Retirements	325	#	......	100	....	#
Work Equipment—Repairs	326	.83	86	14	.71	.12
Work Equipment—Depreciation	327	.29	......	100	....	.29
Work Equipment—Retirements	328	.27	......	100	....	.27
Miscellaneous Equipment—Repairs	329	.02	86	14	.02	....
Miscellaneous Equipment—Depreciation	330	#	......	100	....	#
Miscellaneous Equipment—Retirements	331	.01	......	100	....	.01
Injuries to Persons	332	.30	50	50	.15	.15
Insurance	333	.56	......	100	....	.56
Stationery and Printing	334	.24	10	90	.02	.22
Other Expenses	335	.22	......	100	....	.22
Maintenance Joint Equipment at Terminals—Dr.	336	.20	80	20	.16	.04
Maintenance Joint Equipment at Terminals—Cr.	337	.07	80	20	.06	.01
Totals	......	100.00	......	......	56.89	43.11

#Less than .01 per cent.

Table 3 Column 7

Indirect Maintenance of Way Expense per Dollar of Direct Maintenance of Way Expense.

In computing unit values for Table 3, Column 7 (average Indirect Maintenance of Way and Structure Expense per dollar of Direct Maintenance of Way and Structure Expense), the freight portion of items listed under Indirect Maintenance of Way and Structure Expense, Table A, are totaled for each division; the total thus obtained is divided by the total Direct Maintenance of Way and Structure Expense, Table A.

Table 3 Column 8

Indirect Expense—General and Traffic Expense per Dollar of all Other Expense.

The accounts included under this heading are as follows (Freight portion only):

GENERAL AND TRAFFIC EXPENSE

Accounts 451 to 462, inclusive—(General).
Accounts 351 to 359, inclusive—(Traffic).

ALL OTHER OPERATING EXPENSE

Maintenance of Way and Structures.
Maintenance of Equipment.
Transportation—Rail Line.
Miscellaneous Operations.
Transportation for Investment—Cr.

The Unit Values in Column 8 are obtained by dividing the total General and Traffic Expense for each division by the correspondnig total of All Other Operating Expenses.

Table 3-A

Repairs, Lubricants and Other Supplies for Locomotives—Direct Expense per Locomotive Mile.

The following method is used to obtain repair costs for the various classes of locomotives. This is based on the assumption that the average cost of locomotive repair varies directly as its weight.

A—Number of locomotives of all classes and types		2,544
B—Total weight in pounds (including empty tenders)		701,750,000
C—Average weight per locomotive in pounds (B÷A)		276,000
D—Total locomotive mileage		28,152,000
E—Total locomotive pound-miles (millions) C×D)		7,770,000
F—Total account 308	$	9,212,000
G—Cost per million pound-miles (F÷E)	$	1.185

*Cost per Locomotive Mile (Inc. Tender)**

Mallet, 553,000 pound-miles per loco. mile	$0.66
Santa Fe, 417,000 pound-miles per loco. mile	0.50
Heavy Mikado, 397,000 pound-miles per loco. mile	0.47
Standard Mikado, 350,000 pound-miles per loco. mile	0.42
Heavy Consol., 257,000 pound-miles per loco. mile	0.30

*This cost is obtained by multiplying "Cost per million pound-miles" (G) by the weight of locomotive and tender and dividing by 1,000,000.

Cost of Lubricants and Other Supplies for Locomotives is obtained by dividing total of Accounts 398 and 399 by passenger and freight locomotive mileage (yard excluded).

The average is found and in establishing figures for the various classes, the Heavy Consolidation engine is taken as the average, the Mallet as double the average, the Mikado and Santa Fe are graded between Heavy Consolidation and Mallets.

Table 3-B

Freight Car Repairs per Car Mile
Train Supplies and Expense per 1,000 Car Miles.

To obtain the Freight Car Repairs per Car Mile the total of Account 314 is divided by the corresponding total loaded and empty car mileage including caboose.

To obtain the cost of Train Supplies per 1,000 Car Miles the total of Account 402 Freight portion is divided by the corresponding total loaded and empty car mileage including the caboose.

Table 3-C

Average Cost per Ton Handled through Special Facilities.

The items under this heading, Coal and Ore Wharves, Grain Elevators, and Floating Equipment, have their unit values given uniformly on the basis of tonnage handled through the given facility. The following accounts are included:

Item

Coal and Ore Wharves—Transp. Acct. 375 M. of W. Acct. 243.

Grain Elevators—Misc. Op. Acct. 443 M. of W. Acct. 237.

Floating Equipment—Transp. Acct. 408 M. of W. Acct. 325.

Table 3-D

Fixed Charges Per Car Mile

The items listed under this heading represent the following:

(1) Taxes (basis calendar year).
(2) Joint Facilities and Lease of Road (basis calendar year).
(3) Hire of Equipment (basis calendar year).
(4) Return on Investment (per cent on valuation).

These Expenses are distributed between passenger and freight service on the basis of the ratio of Freight Expense to total operating expenses for the calendar year, the freight portion being 80 per cent. (This per cent to be determined for each particular railroad.)

By applying the above freight percentage to items (1), (2), (3) and (4) and dividing each result by the freight car mileage the unit values are obtained.

Table 4

Direct Enginehouse Expenses per Dispatchment.

The costs given by stations in this table represent the average cost of labor and material per engine dispatched (Passenger, Freight and Yard) from the points named.

Table 5

Direct Yard Expense per Unit Car Received and Cars per Yard Engine Hour, ("Unit Cars" means a car received in the yard from line of road or from connections).

This table is compiled from data given on Individual Yard Expense statements prepared monthly for each yard. These statements are in effect a distribution of the following divisional expenses:

Acct. 377—Yard Masters and Yard Clerks.
Acct. 378—Yard Conductors and Brakemen.
Acct. 379—Yard Switch and Signal Tenders.
Acct. 380—Yard Enginemen.
Acct. 381—Yard Motormen.
Acct. 382—Fuel for Yard Locomotives.
Acct. 384—Yard Switching Power Purchased.
Acct. 385—Water for Yard Locomotives.
Acct. 386—Lubricants for Yard Locomotives.
Acct. 387—Other Supplies for Yard Locomotives.
Acct. 388—Enginehouse Expenses Yard.
Acct. 389—Yard Supplies and Expenses.

In order to arrive at the Direct Expense the amounts charged to Accounts 377, 379, 389, have been deducted from the totals of the above listed accounts. The Direct Expense is then divided by the number of unit cars received in order to obtain the unit costs given in Table 5.

The number of unit cars handled per engine hour is given in the Individual Yard Expense Statement and has been included in Table 5, for the purpose of computing locomotive repair costs.

Table 6

Ratio of Road Locomotive Miles to Train Haul Miles.

The purpose of this table is to provide a method of correcting certain Transportation and Maintenance of Equipment expenses to allow for light and terminal mileage.

In computing the unit value for each division, the total freight train mileage less mileage of engines run light with caboose, is applied as a divisor into the total freight train mileage plus the light and terminal locomotive mileage.

The ratios are given in percentage form and are used as multipliers for the purpose of inflating the following item:

Wages of Road Crews.
Fuel.
Water.
Engine Miles for Lubricants and Supplies.
Enginehouse Expense.
Engine Miles for Repairs to Road Locomotives.

Table 7

Helper Service—Engine Trip Basis.

This table gives helper engine mileage—helping and light—and Direct Transportation Expense per helper engine trip on all helper districts. The class of engine is also noted for convenience in computing helper repairs.

The items of expense included in the cost per trip are as follows:

Wages of Engine Crew.
Fuel.
Water.
Lubricants and Supplies.
Enginehouse Expense.

Table 8

Cost per ton LCL Freight Handled by Station Labor.

This table is based on data furnished by the Station Service Bureau or other source. The unit values are obtained by dividing the expense for platform forces at each station by the corresponding number of tons handled—first handling.

Table 9

Hire of Private Line Equipment Per Car Mile.

The cost per car mile are those in effect at the time the study is made. These figures are to be substituted for the average value of $0.0026 per car mile given under Fixed Charges when privately owned equipment is used for particular commodities.

Table 10

Cost per Ton Hauling and Handling Fuel

The calculated cost of hauling and handling fuel is explained for Table 3, Column 1.

Table 11

Average Number of Crew Hours per Trip.

The average number of crew hours per trip is taken from record showing freight train performance for a suitable period of days or months.

TABLE 1

Engine and Train Crew Wages in Through and Local Freight Service —As of July 1, 1921

Class of Power—Weight on Drivers—Locomotive Series Numbers	Total per 8 Hrs. or per 100 Miles and Hourly O. T. Rate				
	Through Freight		Local and Pickup		
	5-Men	6-Men	5-Men	6-Men	7-Men
Mallet 275,000 lb. and over	$29.31 5.50	$33.79 6.34	$31.55 5.92	$36.43 6.83	$41.31 7.75
Santa Fe 300,000 lb. to 350,000 lb.	$28.01 5.25	$32.49 6.09	$ 30.25 5.67	$35.13 6.59	$40.01 7.50
Mikado 200,000 lb. to 250,000 lb.	$27.32 5.12	$31.80 5.96	$29.56 5.54	$34.44 6.46	$39.32 7.37
Heavy Consolidation and Pacific 170,000 lb. to 200,000 lb.	$27.00 5.06	$31.48 5.90	$29.24 5.48	$34.12 6.40	$39.00 7.31
Light Consolidation and Pacific Mogul and Heavy Six Wheel. 140,000 lb. to 170,000 lb.	$26.68 5.00	$31.16 5.84	$28.92 5.42	$33.80 6.34	$38.68 7.25
Miscellaneous Light Freight, Passenger and Switching Locomotives 100,000 lb. to 140,000 lb.	$26.28 4.93	$30.76 5.77	$28.52 5.35	$33.40 6.26	$38.28 7.18
80,000 lb. to 100,000 lb.	$26.04 4.88	$30.52 5.72	$28.28 5.30	$33.16 6.22	$38.04 7.13

TABLE 2

Rates of Pay for Enginemen, Firemen, Trainmen, Yardmen, etc.—As of July 1, 1921

ENGINEMEN AND FIREMEN

Total per Day or per 100 Miles and Hourly Overtime Rate

Class of Power	Mallet	Class S	Mikado	Consolidation and Pacific		Miscellaneous Lt. Frt. Passenger and Switching		
Weight on Drivers	275,000# andover	300,000# 350,000#	200,000 250,000#	170,000# 200,000#	140,000# 170,000#	100,000# 140,000#	80,000# 100,000#	Under 80,000#
Through Freight.*								
Enginemen	$ 8.40	$ 7.48	$ 7.20	$ 7.04	$ 6.88	$ 6.64	$ 6.56	$ 6.48
Firemen	6.15	5.77	5.36	5.20	5.04	4.88	4.72	4.64
Total	$14.55	$13.25	$12.56	$12.24	$11.92	$11.52	$11.28	$11.12
Engine Crew O. T. Rate.	2.73	2.48½	2.35½	2.29½	2.23½	2.16	2.11½	2.08½
Local and Pickup *								
Enginemen	$ 8.92	$ 8.00	$ 7.72	$ 7.56	$ 7.40	$ 7.16	$ 7.08	$ 7.00
Firemen	6.55	6.17	5.76	5.60	5.44	5.28	5.12	5.04
Total	$15.47	$14.17	$13.48	$13.16	$12.84	$12.44	$12.20	$12.04
Engine Crew O. T. Rate.	2.90¼	2.65¾	2.52¾	2.46¾	2.40¾	2.33¼	2.28¾	2.25¾
Yard.†								
Enginemen	$ 7.72	$ 6.88	$ 6.72	$ 6.56	$ 6.56	$ 6.40	$ 6.40	$ 6.40
Firemen	6.32	5.36	5.20	5.08	5.08	4.96	4.96	4.96
Total	$14.04	$12.24	$11.92	$11.64	$11.64	$11.36	$11.36	$11.36
Engine Crew O. T. Rate.	2.63¼	2.29½	2.23½	2.18¼	2.18¼	2.13	2.13	2.13

*100 miles less, 8 hours or less, constitutes a day's work.

†8 hours constitutes a day's work.

TABLE 2—Continued

FREIGHT TRAINMEN

Occupation or Crew Make-up	Through Service		Local and Pickup Service	
	Per Day or Per 100 Miles	Per Hour of Overtime	Per Day or Per 100 Miles	Per Hour of Overtime
Conductors	$5.80	$1.08¾	$6.32	$1.18½
Flagmen or Brakemen	4.80	0.84	4.88	0.91½
Conductor, Flagman and 1 Brakeman	$14.76	$2.76¾	$16.08	$3.01½
Conductor, Flagman and 2 Brakemen	19.24	3.60¾	20.96	3.93
Conductor, Flagman and 3 Brakemen	....	....	25.84	4.84½

8 hours or less, 100 miles or less, constitutes a day's work. Basis 12½ miles per hour.

YARD TRAINMEN

Rate per	Conductors	Brakemen	Switch Tenders
Day	$6.32	$5.84	$4.40
Hour of Overtime	1.18½	1.09½	0.82½

TABLE 3

Unit Costs, Freight Portion, Applying on Various Divisions

Divisions	Direct Expense				Indirect Expense			
	1 Fuel Hauling and Handling per Ton	2 Water Per 1000 Gallons	3 Station Agents Clerks Supplies per Train Mile	4 Roadway and Track Maint. per 1000 G. T. M.	5 Transp. Expense per Train Mile	6 M. of E. Expense per Dollar Direct M. of E.	7 M. of W. Expense per Dollar Direct M. of W.	8 General and Traffic Expense per Dollar of all Other Operating Expense
First	$1.55	$0.0915	$0.219	$0.605	$0.773	$0.281	$0.195	$0.0535
Second	1.06	0.0973	0.564	0.532	1.377	0.275	0.551	0.0395
Third	1.72	0.0972	0.433	1.046	0.384	0.323	0.355	0.0938
Fourth	0.69	0.0521	0.584	0.253	0.504	0.312	0.274	0.0731
Fifth	0.42	0.0267	0.391	0.420	0.432	0 256	0.223	0.0585

TABLE 3-A

Repairs, Lubricants and Other Supplies for Locomotives—Cost per Locomotive Mile

	Mallet	Santa Fe	Heavy Mikado	Standard Mikado	Heavy Consolidation
Repairs (Running and Classified)	$0.66	$0.50	$0.47	$0.42	$0.30
Lubricants and other Supplies	0.0354	0.030	0.027	0.025	0.0177

TABLE 3-B

Freight Car Repairs and Freight Train Supplies

Freight Car Repairs	$0.0205 per Car Mile
Freight Train Supplies and Expense	$2.24 per 1,000 Car Miles

Table 3-C

Average Cost per Ton Handled Through Special Facilities

Divisions	Coal and Ore Wharves				Grain Elevators		Floating Equipment	
	Handling Coal		Handling Ore					
	Oper'n	Maint.	Oper'n	Maint.	Oper'n	Maint.	Oper'n	Maint.
First.....	....	....	....	....	....	....	$0.4290	$0.4250
Second...	$0.0868	$0.0140	....	....	$0.439	$0.0597	0.0950	0.1852
Third....	....	....	$0.1350	$0.0428	....	....	....	....
Fourth...	0.0234	0.0130	0.1281	0.0137	....	....	....	....
Fifth.....	0.0330	0.0140	0.1161	0.0402	....	....	....	....

Table 3-D

Fixed Charges

Taxes..	$0.00732 per car mile
Joint Facilities and Lease of Road..................................	0.00127 per car mile
*Hire of Equipment..	0.00261 per car mile
Return on Investment..	0.04400 per car mile
Total..	$0.05520 per car mile

(*)Where privately owned equipment is used substitute actual charge per car mile in place of average cost. See Table No. 9.

Table 4

Direct Enginehouse Expense per Dispatchment

Station	Cost	Station	Cost	Station	Cost
A	$2.11	F	$3.07	K	$7.00
B	5.32	G	7.84	L	4.06
C	1.67	H	4.11	M	2.82
D	5.69	I	2.13	N	2.63
E	4.68	J	3.49	O	4.66

Table 5

Direct Yard Expense per Unit Car Received and Cars per Engine Hour

Yard	Cost per Car	Cars per Hour	Yard	Cost per Car	Cars per Hour	Yard	Cost per Car	Cars per Hour
A	$1.06	5.0	F	$1.68	3.0	K	$1.50	5.0
B	1.92	2.0	G	1.19	5.0	L	5.00	1.0
C	0.54	12.0	H	1.00	6.0	M	0.76	8.0
D	0.72	11.0	I	0.46	12.5	N	0.44	17.0
E	0.76	7.0	J	0.54	10.0	O	1.13	4.0

Table 6

Ratio of Road Locomotive Miles to Train Haul Miles

Division	Per Cent	Division	Per Cent	Division	Per Cent
First............	115.4	Third...........	103.8	Fifth..............	116.6
Second..........	113.9	Fourth..........	108.0	Sixth..............	119.3

Table 7

Helper Service—Engine Trip Basis

Helper District	Helper Miles H. & L.	Class of Power	Direct Transportation Expense
A to B	6	Mikado	$14.70
C to D	7	Electric	20.00
E to F	24	Mallet	33.00
G to H	50	Class S	58.50
I to J	70	Consolidation	40.40

Table 8

Cost Per Ton L. C. L. Freight Handled by Station Labor

Station	Cost	Station	Cost	Station	Cost
A	$0.809	F	$0.732	K	$0.575
B	0.608	G	0.826	L	0.427
C	0.780	H	0.908	M	0.457
D	0.597	I	0.757	N	0.532
E	0.655	J	0.719	O	0.474

Table 9

Hire of Private Line Equipment—Per Car Mile

Refrigerator	Tank	Live Poultry	Stock	Heater	Coal and Coke
$0.02	$0.015	$0.015	$0.01	$0.01	$0.015

Table 10

Cost Per Ton—Hauling and Handling Fuel

Divisions	*Net Ton Mileage, Average per Month	Cost of Hauling				Cost of Handling			Cost of Hauling and Handling per Ton
		*Direct Freight Transp. and M. of E. Expense Average per Month	Cost per Net Ton Mile	Average Haul in Miles	Average Cost per Ton	Freight Fuel Disbursed July to November, 1921	Acct. 394-C, July-November	Average Cost per Ton	
First	67,998,600	$288,107	$.00423	355	$1.49	48,312	$ 2,727	$.0565	$1.55
Second	82,727,000	499,125	.00603	240	0.99	84,116	6,210	.0738	1.06
Third	2,162,400	23,558	.01090	240	1.54	5,513	997	.1810	1.72
Fourth	179,815,000	414,835	.00231	170	0.61	93,556	7,157	.0766	.69
Fifth	79,874,000	370,602	.00503	67	0.34	149,229	11,169	.0748	.42

(*)Note—Average net ton mile per month is used as divisor against average direct expense per month.

See note Table No. 3. Column 1—"Derivation of Cost Data"—explaining method of arriving at cost of haul for each division.

Table 11

Average Number of Crew Hours per Trip

Run	Hours	Run	Hours	Run	Hours
A to B	9.7	E to F	9.2	H to I	13.3
B to A	9.7	F to E	9.5	I to H	12.8
C to B	7.2	F to G	7.0	H to J	11.7
B to C	7.8	G to F	6.8	J to H	10.2
D to C	3.1	E to H	9.8	G to K	10.3
C to D	3.9	H to E	8.4	K to G	8.4

Note—Above figures are to be used in connection with Tonnage Freight Service only.

APPLICATION OF TABLES

Direct Transportation Expense

Wages of Road Crews:

Average hours on duty per trip is taken from record .... Table 1 gives total straight pay per day or per 100 miles and the hourly overtime rate according to the class of road engine, the kind of service and the number of men in a crew. Table 2 is used to obtain the pay of engine crews where doubleheaders are operated. After computing the wage expense as above, multiply the result by the percentage in Table 6 in order to include the additional cost of light and terminal engine mileage.

Fuel:

The tons consumed per trip is taken from record .... and the cost is computed on the basis of the prevailing average purchase price plus the cost of hauling and handling on the division under consideration, as shown in Table 3, Column 1. After obtaining this portion of the expense, multiply by the proper percentage taken from Table 6, as explained under "Wages of Road Crews."

Water:

The amount used is obtained by multiplying the tons of fuel per trip by 2,000 (basis of one gallon of water per pound of coal). The cost per 1,000 gallons on various divisions is given in Table 3, Column 2. This expense must be multiplied by the proper percentage taken from Table 6, as explained under "Wages of Road Crews."

Lubricants and Supplies:

Multiply the train miles by the proper divisional percentage, taken from Table 6, to obtain total engine mileage per trip (including light and terminal). The cost per engine mile for various classes of power is given in Table 3-A under "Repairs, Lubricants and Other Supplies for Locomotives."

Enginehouse Expense:

Take the cost per dispatchment from Table 4 for the enginehouse affected and multiply by the proper divisional percentage in Table 6, as explained under "Wages of Road Crews."

Freight Train Supplies and Expenses:

Multiply the car miles, in thousands, per trip by the cost per 1,000 car miles as given in Table 3-B.

HELPER SERVICE:

Obtain the direct transportation expense per helper trip from Table 7, consulting record showing performance of freight trains as to the number of helpers used per train on the helper districts affected.

YARD SERVICE:

Take the cost per car through the yard affected from Table 5 and multiply by the number of cars per train. Where a one way movement through several yards is being considered, use one-half of the tabular cost per car for each of the terminal yards and the full cost per car for intermediate yards. Where a round trip movement is being computed—that is, loaded cars in one direction and empties in the other—simply apply the full cost per car for each yard affected, to the *outbound* trains only.

Operation of Line and Terminal Facilities—Direct Expense

STATION SERVICE:

The charges for Agents, Clerks and Supplies at so much per train mile on divisions affected—see Table 3, Column 3—is applied to all train movements, whether loaded or empty and regardless of commodity. Station Labor will only be applied to those classes of freight known to be involved and when it is necessary to consider this item the cost per ton handled can be taken from Table 8, for the stations affected.

COAL AND ORE WHARVES:

Take the cost per ton handled from Table 3-C when coal or ore shipments requiring handling through such facilities are involved.

GRAIN ELEVATORS:

Take the cost per ton handled from Table 3-C when grain shipments requiring the use of railroad elevators are involved.

FLOATING EQUIPMENT:

Take the cost per ton handled from Table 3-C when any traffic requiring the use of such facilities is involved.

Direct Maintenance of Equipment Expense

ROAD LOCOMOTIVES:

Multiply the train mile by the proper divisional percentage taken from Table 6 to obtain the total engine mileage per trip, including light and terminal. The cost per engine mile for running and classified repairs is given for various classes of locomotives in Table 3-A. These costs apply, for the given classes of power, on all parts of the railroad.

HELPER LOCOMOTIVES:

The total mileage—helping and light—for each helper trip is given in Table 7. The cost per engine mile for running and classified repairs is given for various classes of locomotives, in Table 3-A, as explained under "Road Locomotives."

YARD LOCOMOTIVES:

Table 5 gives the cars handled per engine hour based on the number of all inbound cars into the yard. In order to obtain the yard engine hours per train, this tabular figure should be doubled and then divided into the number of cars handled in such train, whether into or out of the yard affected. The tabular figure is doubled because it is considered that yard engine hours are about equally divided between the operations of handling cars of inbound and outbound trains, whereas the usual method of measuring yard engine performance is on the basis of inbound cars only. Engine hours per train—obtained as above—multiplied by 6 to reduce to a mileage basis, and then multiplied by the repair cost per mile in Table 3-A will give Yard Locomotive Repairs per train, into or out of the yard.

FREIGHT CARS:

Multiply the car mileage per train by the cost per car mile as developed for all divisions of the railroad and shown in Table 3-B.

FLOATING EQUIPMENT:

The cost per ton handled is given in Table 3-C and should be applied only where traffic requiring the use of such equipment is involved.

Direct Maintenance of Way Expense

ROADWAY, TRACK, ETC.:

The gross ton mileage per train is multiplied by the cost per 1,000 gross ton miles for the divisions affected, as indicated in Table 3, Column 4.

COAL AND ORE WHARVES:

The cost per ton handled is given in Table 3-C and should be applied only where traffic requiring the use of such facilities is involved.

GRAIN ELEVATORS:

The cost per ton handled is given in Table 3-C and should be applied only where traffic requiring the use of such facilities is involved.

Indirect Expense

TRANSPORTATION:

The train miles per trip is multiplied by the cost per train mile for the divisions affected—see Table 3, Column 5.

MAINTENANCE OF EQUIPMENT:

The total Direct Maintenance of Equipment Expense is multiplied by the cost per dollar as indicated in Table 3, Column 6, for the divisions affected.

MAINTENANCE OF WAY:

The total Direct Maintenance of Way Expense is multiplied by the cost per dollar as given in Table 3, Column 7, on divisions affected.

GENERAL AND TRAFFIC:

To obtain this cost, total all of the following expenses—Direct Transportation, Direct Expenses of Operation of Line and Terminal Facilities, Direct Maintenance of Equipment, Direct Maintenance of Way, Indirect Transportation, Indirect Maintenance of Equipment, and Indirect Maintenance of Way—and multiply by the cost per dollar as given in Table 3, Column 8, for the divisions affected.

Fixed Charges

The unit values of items given under this head in Table 3-D are to be multiplied by the total car miles per trip for the run being considered.

The following tables give the result of solving a problem by the application of this method by determining the cost of handling coal between two points and of comparing the economic advantages or disadvantages of two routes.

Cost of Hauling Coal from A to E—Comparison by ACD and AXD Routes—Recapitulation

	Cost per Car via ACD Route	Cost per Car via AXD Route	Saving or Loss by AXD Route	
			Saving	Loss
Road Crew Wages	$ 5.24	$ 4.72	$ 0.52	....
Fuel, Water, Supplies, etc	10.61	9.26	1.35	....
Helper Service	3.20	4.02	....	$0.82
Yard Service	5.20	6.78	....	1.58
Coal and Ore Wharf Operation	4.33	4.33	....	....
Locomotive Repairs	8.29	7.97	0.32	....
Car Repairs	11.62	13.51	....	1.89
Total Direct Operating Expense	$48.49	$50.59	....	$2.10
Direct Maintenance of Way and Structures	$11.40	$14.89	....	$3.49
Constant Transp. Expense	$10.83	$ 9.95	$0.88	....
Constant Maint. of Equipment	5.54	5.81	....	$0.27
Constant Maint. Way and Structures	4.04	4.18	....	0.14
General and Traffic Expense	4.50	4.61	....	0.11
Total Indirect Operating Expense	$24.91	$24.55	$0.36	....
Total Operating Expense	$84.80	$90.03	....	$5.23
Fixed Charges	31.24	36.26	....	5.02
Grand Total	$116.04	$126.29	....	$10.25

Cost of Hauling Coal—A to E—via AXD Route

Train Districts	A and X		X and G		G and D		D and E		Tota
	East	West	East	West	East	West	East	West	E. &
Items									
Haul in Miles	48	47	114	110	95	97	75	72	658
Class of Road Locomotive	Mikado	Mikado	Mallet	Mallet	Mikado	Mikado	Mikado	Mikado	......
Train Consist	65-lds.	90-mts.	65-lds.	90-mts.	70-lds.	90-mts.	71-lds.	80-mts.	......
Gross Train Load—Tons	4550	1800	4550	1800	4900	1800	4970	1600	......
Cost per Car									
Road Crew Wages	$ 0.39	$0.28	$ 1.25	$ 0.74	$ 0.48	$ 0.33	$ 0.70	$ 0.55	$ 4.7
Fuel, Water, Lubricants, Engine and Train Supplies, Enginehouse Expense	0.69	0.52	2.16	1.57	1.24	1.05	1.05	0.98	9.2
Helper Service	0.35	0.14	1.54	0.55	0.28	....	1.16	....	4.0
Yard Service	0.56	0.68	0.68	0.42	0.42	0.72	0.72	2.58	6.7
Coal and Ore Wharf Operation	....	....	....	....	....	....	4.33	....	4.3
Locomotive Repairs	0.54	0.38	2.34	1.22	0.85	0.63	1.14	0.87	7.9
Car Repairs	0.99	0.96	2.34	2.26	1.95	1.99	1.54	1.48	13.5
Total Direct Road Expense	$ 3.52	$ 2.96	$10.31	$ 6.76	$ 5.22	$ 4.72	$10.64	$ 6.46	$50.5
Direct M. of W. and S. Expense	$ 1.96	$ 0.55	$ 4.66	$ 1.29	$ 1.68	$ 0.49	$ 3.49	$ 0.77	$14.8
Indirect Transp. Expense*	0.61	0.43	1.45	1.01	1.48	1.17	2.05	1.75	9.9
Indirect M. of E	0.38	0.33	1.16	0.86	0.87	0.82	0.74	0.65	5.8
Indirect M. of W. and S	0.29	0.08	0.68	0.19	0.46	0.14	1.92	0.42	4.1
General and Traffic Expense	0.38	0.24	1.03	0.57	0.71	0.54	0.74	0.40	4.6
Total Indirect Expense	$ 1.66	$ 1.08	$ 4.32	$ 2.63	$ 3.52	$ 2.67	$ 5.45	$ 3.22	$24.5
Total Operating Gen. & Traffic Expense	$ 7.14	$ 4.59	$19.29	$10.68	$10.42	$ 7.88	$19.58	$10.45	$90.0
Fixed Charges	2.60	2.59	6.29	6.07	5.24	5.36	4.14	3.97	36.2
Grand Total	$ 9.74	$ 7.18	$25.58	$16.75	$15.66	$13.24	$23.72	$14.42	$126.2

*Includes Station Agents, Clerks and Supplies, from "Operation of Line and Terminal Facilities."

Cost of Hauling Coal—A to E—via ACD Route

Train Districts	A and C				C and D		D and E		Total
	A and B		B and C						
	East	West	East	West	East	West	East	West	E.& W
Items									
Haul in Miles	23	23	76	77	110	110	75	72	566
Class of Road Locomotive	Mallet	Mallet	Mallet	Mallet	Mikado	Mikado	Mikado	Mikado	......
Train Consist	64-lds.	50-mts.	32-lds.	50-mts.	70-lds.	90-mts.	71-lds.	80-mts.	......
Gross Train Load—Tons	4460	1000	2240	1000	4900	1800	4970	1600	......
Cost per Car									
Road Crew Wages	$0.28	$0.28	$1.62	$0.89	$0.54	$0.38	$0.70	$0.55	$5.24
Fuel, Water, Lubricants, Engine and Train Supplies, Enginehouse Expense	0.50	0.43	3.20	1.96	1.37	1.12	1.05	0.98	10.61
Helper Service	....	....	1.76	....	0.28	....	1.16	....	3.20
Yard Service	0.56	....	....	0.31	0.31	0.72	0.72	2.58	5.29
Coal and Ore Wharf Operation	....	....	....	....	....	....	4.33	....	4.33
Locomotive Repairs	0.37	0.37	2.66	1.24	0.94	0.70	1.14	0.87	8.29
Car Repairs	0.47	0.47	1.56	1.58	2.26	2.26	1.54	1.48	11.62
Total Direct Road Expense	$2.18	$1.55	$10.80	$5.98	$5.70	$5.18	$10.64	$6.46	$48.49
Direct M. of W. and S. Expense	$1.36	$0.39	$2.23	$0.65	$1.95	$0.56	$3.49	$0.77	$11.40
Indirect Transportation Expense*	$0.33	$0.43	$1.96	$1.27	$1.71	$1.33	$2.05	$1.75	$10.83
Indirect M. of E	0.22	0.21	1.08	0.72	1.00	0.92	0.74	0.65	5.54
Indirect M. of W. and S.	0.29	0.08	0.50	0.14	0.54	0.15	1.92	0.42	4.04
General and Traffic Expense	0.30	0.18	0.97	0.51	0.80	0.60	0.74	0.40	4.50
Total Indirect Expense	$1.14	$0.90	$4.51	$2.64	$4.05	$3.00	$5.45	$3.22	$24.91
Total Operating, Gen. & Traffic Expense	$4.68	$2.84	$17.54	$9.27	$11.70	$8.74	$19.58	$10.45	$84.80
Fixed Charges	1.27	1.27	4.20	4.25	6.07	6.07	4.14	3.97	31.24
Grand Total	$5.95	$4.11	$21.74	$13.52	$17.77	$14.81	$23.72	$14.42	$116.04

*Includes Station Agents, Clerks and Supplies, from "Operation of Line and Terminal Facilities"

[2]FEASIBILITY AND ECONOMY OF THROUGH ROUTING OF SOLID TRAINS AND ITS EFFECT UPON THE CAPACITY OF TERMINALS

(1) The collection of cars into groups with the same or similar destination for movement intact through intermediate terminals to destination is practical and will increase the number of cars which can be handled through terminals and reduce the cost chargeable to terminal operation.

(2) Classification should be made according to a systematic plan based on a thorough survey of the origin and destination of all cars, loaded and empty, and of all classification facilities available. The plan should be comprehensive in scope and cover all cars handled.

(3) The plan should provide for the assembling of cars for the same destination into groups as early in their movement as possible.

(4) To insure maximum success and minimum interference with the plan, all delays to cars after being assembled into groups should be reduced to a minimum by the removal of the causes for these delays prior to their grouping. This should include such arrangements for car inspection and repair as will obviate the necessity for setting out cars in bad order short of their destination except as the result of an accident.

(5) Supervision of the plant should be centered in a system officer with a knowledge of the requirements of the system and with authority to enforce adherence to the plan.

[3]OPERATION OF TRAINS AGAINST CURRENT OF TRAFFIC ON MULTIPLE TRACKS

Where the volume and distribution of traffic on a multiple track line are such as to cause delays to trains sufficiently serious to warrant the consideration of means of effecting relief, the operation of trains against the current of traffic is, with suitable protection, recommended as safe and as affording a means of increasing capacity at a small expenditure comparable with the cost of additional facilities sufficient to give relief.

[4]METHOD FOR THE DETERMINATION OF PROPER ALLOWANCES FOR MAINTENANCE OF WAY EXPENSES DUE TO INCREASED USE AND INCREASED INVESTMENT

(I) ALLOWANCES FOR INCREASED INVESTMENT

Increases in investment are the net changes in Capital Account resulting from physical changes in a property. Portions of such increases may be due to acquisitions of lands, to enhanced costs of replacing in kind existing facilities, and to various other causes which cannot affect or augment the maintenance requirements of the property. Other portions of the increases may represent substitutions of so-called permanent for temporary structures for the purpose of reducing maintenance and still other portions cover numerous units of property in no wise similar in their maintenance requirements. From this it is apparent that Increased Investment is not a direct or proper measure of increased maintenance requirements. These requirements can be developed only from consideration of the property units actually represented by increases in investment in fixed property which for present purposes may be classified as follows:

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[2] Adopted, Vol. 25, 1924, pp. 735, 1317.
[3] Adopted, Vol. 23, 1922, pp. 761, 1145; Vol. 26, 1925, pp. 910, 1350.
[4] Adopted, Vol. 26, 1925, pp. 911, 1351.

(A) WAY, including items chargeable to roadbed and track accounts.

(B) STRUCTURES, including bridges and buildings and the miscellaneous items not otherwise classified.

(A) Investments—Way

WAY, that is, roadbed and track, is responsible for about three-fourths of the total cost of maintaining fixed property and generally absorbs the major portion of investments for increases in the railroad plant either through extensions of road or increases in capacity of existing property.

Changes in the amount and character of WAY represented by increases in investment are readily measured in track miles. In order to determine the added maintenance requirement, the different classes of trackage involved should be expressed in terms of equivalent main track by means of the equated track mile plan. Where the data are available this plan may be extended to include less important track items and thus tend to develop more accurate results.

An illustration of the plan with factors sometimes used follows:

A mile of first main track is given a weight of	1.00
A mile of other main track is given a weight of	0.80
A mile of any other track is given a weight of	0.50

This weighting applied to a concrete example yields the following:

NORTH AND SOUTH RAILROAD

Miles Maintained	*Base Period Miles*	*Comparison Period Miles*
(a) First main track	100	110
(b) Other main track	80	90
(c) All other tracks	30	40
Total	210	240
Equated Miles Maintained		
(d) First main track (Item (a) × 1.00)	100	110
(e) Other main track (Item (b) × 0.80)	64	72
(f) All other tracks (Item (c) × 0.50)	15	20
TOTAL	179	202

Factor of Increase in Way $\frac{202}{179} = 1.13$

Assuming that the normal expenditures for maintaining Roadbed and Track or Way at Base Period costs amounted to $237,000, the allowance for Way to be maintained in the Comparison Period would be $237,000 × 1.13 or $267,810. This allowance, however, is subject to the previously mentioned adjustments for differences in price levels and in the use made of the property in the Base and Comparison Periods, which will be more fully developed in the ensuing discussion.

Indications are that the cost of superintendence varies almost directly with the equated track miles maintained and it is, therefore, suggested that charges to this account be included with the costs of maintaining roadbed and tracks.

(B) Investments—Structures

The accounts in this general group are of such a nature that a physical comparison is virtually impossible. As previously stated, the increase in investment, measured in dollars added to Capital Account, cannot be used directly as a measure of the changes in the amount and character of property units to be maintained. The cost of maintaining a dollar's worth of property can readily be obtained with reasonable accuracy, but the result obtained by multiplying this unit cost by the increase in investment is generally so approximate as to be worthless.

This basis might hold on a newly constructed railroad, but has many disadvantages when applied to the older roads. There are few carriers whose investment accounts reflect the true cost of the physical property and virtually no railroad has an accurate division of its investment in fixed property between the primary accounts. This is particularly true in cases where roads have passed through receivership and have been sold for fixed amounts. Furthermore, the investment accounts generally do not include any properties which, when constructed, were paid for out of Operating Expenses or Income. There are also many other analogous items which make it impossible to use Investment Accounts for the purpose of accurately measuring the difference in amount of property.

In view of the foregoing, it is our recommendation that the estimated cost of reproduction new, as indicated in the underlying Engineering Reports of the Interstate Commerce Commission, prepared in connection with the Federal Valuation, be used for this purpose in lieu of the so-called Investment Account. Although the inventories vary with the valuation dates of respective carriers, these reproduction estimates are in all cases priced as of 1914.

Adjustment must be made for the difference in price level between 1914 and the period of normal maintenance selected as the Base Period, and reproduction cost of the fixed property maintained as of valuation date must be adjusted for additions and deletions that occurred between valuation date and the Base Period. The relationship between the reproduction cost of Base Period property and maintenance expenses may then be determined. Assuming that the cost of labor and material used in construction will vary from year to year in the same way as labor and material used in maintenance, this ratio can be used in different periods without further adjustment, providing the general character of the property does not change materially.

As additions to the property between the Base Period and the Comparison Period will probably not be distributed between buildings, bridges, signal systems and other classes of structures in the same proportions as these classes made up the Base Period property, it is advisable to segregate both the Base Period property and the additions either by the Interstate Commerce Commission's primary accounts or by groups of these primary accounts. This segregation is made possible by the fact that for each primary capital account there is a corresponding maintenance account.

A complete analysis should be made of all changes—both debits and credits—in the investment accounts other than roadway and track, between the Base and Comparison Periods. This analysis will permit eliminating from investment increases those items having no effect upon maintenance. It will disclose some installations made for the purpose of reducing maintenance and other installations provided for the purpose of facilitating and yielding net savings in operation, although in many cases materially augmenting the maintenance requirements. Occasionally these two types of installations represent a relatively small percentage of the total increase in investment in an account, or to a certain extent their effects on maintenance will equalize and therefore do not require special treatment. Where an intensive betterment program is involved, it will be necessary to segregate these items and to adjust the maintenance necessities on the basis of the relations between maintenance requirements of the betterments and of the items which they replace.

Having determined from analyses of increases in the several investment accounts, those items which should be eliminated because they involve no additional maintenance, and other items which may require special treatment, factors for increases in maintenance units may be developed in accordance with the method which follows. It should be remembered that the revision of charges and credits to capital account so that the amount used in this computation is the reproduction cost of the net addition to the property requiring maintenance on approximately the same scale as the average of the Base Period property is of necessity somewhat approximate. Refinements not justified by the accuracy of the original data and of practical methods that have to be followed in converting investment into maintenance expense should not be used.

In the following example all factors for increases in prices are relative to the prices of 1914 as 1.00:

Method of Determination of Factors for Increase in Maintenance Units Represented by Increases in Investment in Structures' Accounts

	Item	*Acct. Bridges*
1.	Engineering report, estimated reproduction cost of property as of valuation date (say 1916) at 1914 prices	$400,000
2.	Factor for increase in prices 1914 to base period	1.21
3.	Reproduction cost of 1916 property at base period prices (1) × (2)	484,000
4.	Added investment 1916 to base period	20,000

	Item	*Acct. Bridges*
5.	Average factor for increase in prices 1916 to base period: 1916 factor 1.10; base period factor 1.21. Factor for increase 1.21/1.10 or 1.10 whence average factor over period in which investment is being increased is	1.05
6.	Added investment 1916 to base period equated to base period prices (4) × (5)	21,000
7.	Reproduction cost of average amount of property maintained during base period at base period prices (3) plus (6)	505,000
8.	Base period maintenance expense	10,100
9.	Maintenance ratio (8) divided by (7)	0.02
10.	Added investment, base period to comparison period	$ 85,000
11.	Portion of (10) which investigation indicates does not reflect additional maintenance requirements	25,600
12.	Portion of (10) involving additional maintenance (10) — (11)	59,400
13.	Average factor for increase in prices base period to comparison period: Base period factor 1.21, comparison period factor 2.06, factor for increase 2.06/1.21 or 1.70 whence average factor during investment increases is	1.35
14.	Added investment involving added maintenance base period to comparison period dequated to base period prices, (12) divided by (13)	44,000
15.	Factor for increase in property involving maintenance in comparison period: (14) divided by (7), plus 1.00	1.087
	If desired, the estimated cost of maintaining the additional property may be developed as follows:	
16.	Estimated cost of maintaining additional property at base period prices (14) × (9)	880
17.	Estimated cost of maintaining additional property at comparison period prices (16) × 1.70	1,496
18.	Estimated cost of maintaining base period property at comparison period prices (8) × 1.70	17,170
19.	Estimated cost of maintaining comparison period property at comparison period prices (17) plus (18)	18,666

Item No. 19 is subject to previously mentioned adjustment for difference in use, which will be further developed in the ensuing discussion.

In the event that the interval between the Base and Comparison Periods includes several years in which there were marked fluctuations in price levels or in the amount of the increases in investment, it may be found advisable to treat each year separately. That is, instead of using a simple average price factor for the entire term, the net increase in investment in each year should be dequated to Base Period levels.

General

It is assumed that the railroad under consideration has had a reasonably uniform growth during the years covered by this computation and for a considerable period prior thereto. Additions to the property this year will probably require little maintenance for many years to come; on the other hand additions made ten or fifteen years ago may require more than the average amount of maintenance in the current year. If the growth of the property has been reasonably uniform, as assumed, these extreme conditions will produce an average that can be computed with reasonable accuracy by the methods indicated.

If the growth of the property has been small and distributed between roadbed and track and the different classes of structures with reasonable uniformity, a sufficiently close approximation of the allowance for increased investment may be obtained by using the equated track mile as the measure of all fixed property. This method is illustrated in Appendix B.

(II) ALLOWANCES FOR INCREASED USE

It is well recognized that the cost of maintenance of way and structures becomes greater with increased use of or traffic handled over a railway and that the converse also is true. While responses to increased requirements are rarely immediate, nevertheless the relation between traffic handled and maintenance costs is reasonably constant, if examined over a sufficient term of years. Extended analyses of the performances of numerous representative railways confirm this conclusion, but show that, unlike transportation expense, which varies almost directly, maintenance expense varies at a very much less rate than changes in traffic density.

The relation of use and maintenance expense is incapable of exact determination, but can be approximated within limits sufficiently accurate for practical purposes in studying properties as a whole. This may be accomplished by a method based upon a segregation of the maintenance necessitated by the existence of the property and the use made of it. The principles of this method, in some more or less complete form, have previously been used in comparisons of properties, or past performances. This method was thoroughly tested out in the subsequent analyses of maintenance performances during the period of Federal Control.

A consideration of this method requires discussion of:

(A) The "Use" Unit.
(B) The Influence of "Use" on Maintenance Accounts.
(C) The Maintenance Unit.
(D) Solution of the Problem.

These sub-divisions are here briefly outlined:

(A) The "Use" Unit

In general, every railroad produces transportation units in the two quite distinct classes of freight and passenger service. Since no common transportation unit can adequately cover both, it is necessary to combine and measure the effect through a suitable equated unit.

The "Use" Unit should be related in some definite way to the two classes of traffic, which are in general distinguished by the two principal characteristics of weight and speed, which directly influence maintenance requirements. The following transportation units, train miles, engine miles, net ton miles, gross ton miles, car miles, engine ton miles, and locomotive tractive power miles, have been used to a greater or less extent as measures of use, but these are inadequate because they are singly not sufficiently inclusive to cover the normal variations in traffic.

Every ton of locomotives, cars, and their contained loads, makes an impression in some quite distinct manner upon the physical property over which it is moved. It is an acknowledged fact that a ton of locomotive passing has a relatively greater effect than a ton of cars; and likewise the greater the speed of locomotives and cars, the greater the destructive effect. Freight service and passenger service are distinguished by a difference in average speed of movement. There are, of course, portions of each service which approach each other in characteristics of weight and speed; nevertheless these two are, in general average, separated by differences in speed.

There seems to be good reason for selecting the freight gross ton as the basis in the equation scheme on account of its general availability, its relatively large proportion of the weight element on most railroads, and the further general similarity of gross tons. Gross tons of freight cars are, therefore, taken as unity; freight-locomotive-tons are given a factor of two; passenger-locomotive-tons a factor of three; and passenger-car-tons, a factor of one. The factor of one for passenger-car-tons is in recognition of the fact that higher standards of equipment construction, and the better maintenance of passenger equipment over that of the freight cars, tends to mitigate the damage resulting from a higher speed, as well as the special requirements demanded thereby.

Passenger service requires, or at least dictates, a higher standard of maintenance than is required for exclusive freight service. This in turn necessitates more immediate reparation in wear and tear. The existence of a higher standard automatically operates to reduce the wear and tear from the co-existent freight service. Various attempts have been made, without convincing success, to measure the actual difference in reparation attributable to freight and passenger service. The difficulties of measurement are due to the limitations of accounting records, and the long interval of time required to include the cycles of major material renewals, as well as the determination of relative maintenance standards.

Trials which have been made from time to time on various typical railroads indicate that the allocation of "use" units as between freight and passenger service, based on the equated plan outlined, over any considerable period, seem to give a reasonable expression of the maintenance that should be charged against these two services, at least within limits of accuracy consistent with the practical application of such a method, and the confirmation of the best maintenance judgment available for these properties. It is recognized, of course, that there are some outstanding exceptions such as properties on which the performance of fast freight movement is high, or is increasing out of proportion to the other tonnage movement. These cases require a special treatment in accord with the principles suggested.

(B) The Influence of "Use" on Different Maintenance Accounts

There are three classifications of accounts in their relation to "use":

(1) Those varying directly with use,
(2) Those varying independent of use,
(3) Those varying with combined effect of use and other agencies such as weather stress.

The effect of "use" on (1) is absolute, on (2) is zero, and on (3) is fairly determinable by a study of data checked by experienced maintenance judgment.

The influence of "use" on primary accounts may be summarized as follows:

(201) Superintendence.—This account is affected in about the same degree as the supervised labor in the other accounts.

(212) Ties.—This account is affected in a degree varying with the density of traffic. In light traffic situations, the effect may be zero, due to the decay life being the limiting feature; whereas under heavy traffic and trying locations, such as curvature, grades, etc., the effect will be great. It is recognized that the mechanical action of passing wheel loads tends to hasten the decay of ties; in the case of light traffic lines, this influence may not materialize to shorten appreciably the life of the tie, while under heavy traffic conditions the mechanical wear is the determining factor in tie life. The relative effects may be materially varied by a change in the practice of protecting the tie against mechanical wear. Different percentages varying with the characteristics of the location, or road under consideration, should be ascribed to this account.

(214) Rail.—Except in special cases, weather stress is negligible, making the account directly affected by traffic. Substantial increases in wheel loads affect the useful life of rail, but this is a special element in the difference of use.

(216) Other Track Material.—Weather stress has such a slight effect on this item that the account may be treated in the same manner as rail.

(218) Ballast.—The degree to which traffic affects this account varies with the depth and quality of ballast, density and character of traffic, and the quality of subgrade. Outside influences, such as foreign material blown in (not dropped from equipment), subsequent plant growth, fouling due to imperfect ditching, slides, etc., are not directly attributable to traffic. The traffic effect is by far the controlling item in this account.

(202) Roadway Maintenance.—This account is but slightly affected by use. In some cases where the data are sufficiently complete, it may be desirable to place values on certain sub-divisions of this account. In any event the influence of use cannot be large.

(220) Tracklaying and Surfacing.—This is the largest and most important account, and the one which is most immediately responsive to fluctuations in traffic. This account carries the labor items for the important material accounts such as rail, ties, ballast, and other track material; consequently that labor is affected by traffic in the same degree as the corresponding material. The largest item in this account is "track maintenance," which is closely related to traffic influences. In the case of roads with light or moderate traffic density and corresponding roadway standards, increases in traffic make themselves immediately evident and require more prompt liquidation in the expenditures for labor to restore condition of line, surface, etc., than on roads of higher standards where the damage may be largely accrued. Wherever there has been a temporary lowering of physical standard due to deferred application of material, a compensation must be made, at least temporarily, by larger expenditures for labor than would otherwise be normal in the effort to maintain a reasonable standard of line and surface.

(221) Right-of-Way Fences	Effect of use negligible
(223) Snow and Sand Fences, and Snow Sheds..	
(225) Crossings and Signs..........................	
(272) Removing Snow, Ice and Sand.............	
(269) Roadway Machines	

(271) Small Tools and Supplies.—This account is related to the labor items in maintenance, so that it is, to some degree, affected by increases in traffic.

(208) Bridges, Trestles and Culverts.—This account is affected by traffic depending largely on the character of the structures. As a whole, the degree of effect is not very large.

(206) Tunnels and Subways	These accounts are but slightly affected.
(210) Elevated Structures	
(227) Station and Office Buildings	
(229) Roadway Buildings	
(237) Grain Elevators	
(239) Storage Warehouses	
(241) Wharves and Docks	
(243) Coal and Ore Wharves	
(245) Gas Producing Plants	
(253) Power Plant Buildings	
(255) Power Substation Buildings	
(265) Miscellaneous Structures	

(231) Water Stations	These are affected to a moderate degree, varying also with the character of the structure.
(233) Fuel Stations	

(204) Underground Power Tubes	These are so slightly affected, if at all, that they may be disregarded. Special cases can readily be disclosed by the data.
(251) Power Plant Dams, Canals and Pipe Lines	
(257) Power Transmission Systems	
(259) Power Distribution Systems	
(261) Power Line Poles and Fixtures	
(263) Underground Conduits	

(247) Telegraph and Telephone Lines.—This account is so slightly affected that it may be disregarded.

(249) Signals and Interlockers.—This account is obviously affected by traffic.

(267) Paving	These are not affected to a degree to warrant consideration.
(273) Assessments for Public Improvements	

(274) Injuries to Persons	Affected by increases in volume of business necessitating increases in labor, also by increases in the frequency of trains, which create greater probabilities of accidents.
(275) Insurance	

(302) Shop Machinery	These are Maintenance of Equipment accounts which, on account of their somewhat fixed character, are sometimes considered analogous to, and included with, M. W. & S. expenditure comparisons. They may be included or eliminated to suit the circumstances of each case. These accounts are influenced by the amount of work done in the shopping of locomotives and equipment which in turn have been affected by traffic.
(304) Power Plant Machinery	
(306) Power Sub-Station Apparatus	

Each of the above primary accounts includes the appropriate depreciation accounts.

As an illustration of the general application of this method resort is had to the use of readily available I. C. C. records of M. W. & S. expenses for all Class I railways for the three-year period ending June 30, 1917.

In the following table, Col. (3) gives the percentage which each account is of the whole M. W. & S. expenditures. In Column (4) is outlined the percentage which each account is affected by "Use." These percentages are average values, consistent with average conditions and performances of all the railways embraced by the statement. These percentages may be varied to suit the circumstances of each particular problem.

The results derived from the application of this method and set forth in the table may be summarized as follows:

> —Way absorbs 72.98 per cent of total M.W.&S. expense and 40.38 per cent of the expense for Way varies directly with traffic so that of the increase in M.W.&S. expense due to a gain in traffic Way would account for 0.7298×0.4038 or 29.47 per cent.
>
> —33.13 per cent of total M.W.&S. expense varies directly with use so that a gain of 100 per cent in use would result in a potential maintenance expense increase of 33.13 per cent or only slightly more than involved by Way only.

Maintenance of Way and Structure Accounts (1)	Account No. (2)	Per Cent of Total M. W. & S. Expense (3)	Per Cent Affected by Use (4)	Per Cent of Total M. W. & S. Expense Affected by Use (5)
1. Superintendence	201	5.69	20	1.14
2. Ties	212	15.41	30	4.62
3. Rails	214	2.99	100	2.99
4. Other Track Material	216	4.52	100	4.52
5. Ballast	218	1.88	80	1.50
6. Roadway Maintenance	202	10.96	...	....
7. Tracklaying and Surfacing	220	25.91	55	14.25
8. Roadway Fences	221	.87	...	....
9. Snow, Sand Fences, etc.	223	.11	...	....
10. Crossings and Signs	225	1.30	...	....
11. Roadway Machines	269	.45	...	....
12. Small Tools and Supplies	271	1.13	40	.45
13. Removing Snow, Ice, etc.	272	1.76	...	....
Sub-Total—Way		72.98	40.38	29.47
14. Bridges, Trestles & Culverts	208	7.38	10	.74
15. Tunnels and Subways	206	.32	10	.03
16. Elevated Structures	210	.01	...	....
17. Station & Office Buildings	227	3.93	...	....
18. Roadway Buildings	229	.53	...	....
19. Water Stations	231	1.31	10	.13
20. Fuel Stations	233	.53	15	.08
21. Shops, Enginehouses	235	2.45	10	.25
22. Grain Elevators	237	.06	...	....
23. Storage Warehouses	239	.01	...	....
24. Wharves and Docks	241	.61	10	.06
25. Coal and Ore Wharves	243	.55	10	.06
26. Gas Power Plants	245	.01	...	....
27. Power Plant Buildings	253	.07	...	....
28. Power Sub-Station Buildings	255	.01	...	....
29. Miscellaneous Structures	265	.01	...	....
Sub-Total—Structures		17.87	7.55	1.35

30. Underground Power Tubes...	204	....*	...	....
31. Power Plt. Dams & Pipe Lines	251	....*	....	....
32. Power Transmission Systems.	257	.03	...	....
33. Power Distribution Systems..	259	.25	...	....
34. Power Line Poles & Fixtures	261	.03	...	....
35. Underground Conduits	263	....*	...	....
Sub-Total—Power Facilities	...	0.31	...	....
36. Telegraph & Telephone Lines.	247	1.11	...	....
37. Signals & Interlockers........	249	2.67	30	0.80
Sub-Total—Wire & Signal Systems	...	3.78	21 16	0.80
38. Shop Machinery	302	2.76	40	1.10
39. Power Plant Machinery......	304	.44	5	.02
40. Power Sub-Station Apparatus.	306	.03	.....	....
Sub-Total—M. of E. Plant Maint.	...	3.23	34.67	1.12
41. Paving	267	.05	.....	....
42. Assessments Public Improvs..	273	.07	.....	....
43. Injuries to Persons...........	274	.73	50	.37
44. Insurance	275	.61	....	....
45. Stationery and Printing......	276	.20	10	.02
46. Other Expenses	277	.17	.....	....
Sub-Total—Miscellaneous .	...	1.83	46.92	0.39
Totals	...	100.00	.....	33.13

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*Less than .01 per cent.

(C) The Maintenance Unit

There must be a maintenance unit related to the use unit for making comparisons. From the foregoing analysis of Maintenance Accounts it is apparent that Way absorbs about 73 per cent of total expense and represents 29.47/33.13 or 88.95 per cent of the total effect of use on M.W.&S. expenses so that a track unit would be the most inclusive related property unit to use.

Maintained mileage will adequately serve the purpose in comparisons for different periods of time during which there has been no material change in the relative influence of use as between primary and secondary tracks. In the event of such changes, a refinement should be introduced by using the equated track mile plan to express an approximate relation of maintenance necessity as between different classes of track.

(D) Solution of the Problem

The segregation of use effect on the individual maintenance accounts permits the treatment of each in line with special situations which may vary from the average. Comparisons may be made as outlined for different periods of time for a property as a whole, or sub-divisions of the same for which comparative data may be available.

This method determines the potential maintenance requirement caused by a use of the property regardless of whether the same has been met, so that in making comparisons it is essential to determine normal maintenance incident to the peculiar condition of the property by taking into account any deferment or appreciation of maintenance. It is understood that in using expenditures for comparison periods, the accounts must be purged of any unusual adjustment which would prevent their adequately reflecting maintenance performance.

The several steps in the solution of the problem are:

(1) Compile separately for the Base and Comparison Periods, total ton-miles of lading, cars and locomotives passing over the maintained mileage of the railway.

(2) Adjust total ton-miles to equivalent gross ton-miles by use of the weighting referred to in Section II—A or

Net freight ton-miles	× 1
Freight car ton-miles	× 1
Passenger car ton-miles	× 1
Freight locomotive ton-miles	× 2
Passenger locomotive ton-miles	× 3
Total equivalent gross ton-miles	

(3) Determine equated track mileages maintained separately for both periods as described in Section I.

(4) Reduce total equivalent gross ton-miles to average density per equated track mile separately for both periods — (2) divided by (3).

(5) Develop increase in traffic density from (4).

(6) Set up Base Period M.W.&S. expenses and apply percentages of effect of use as indicated in Table of Section II—B.

(7) Factor for difference in use will be 1.00 plus (per cent increase in traffic shown by Item No. 5) (per cent effect found in Item No. 6).

Assuming that the increase in traffic density is 30 per cent and "use effect" on total M.W.&S. is 33.13 per cent, then the factor for increased use will be 1.00 plus 0.30 × 0.3313, or 1.099, that is, the increase in use has increased the maintenance requirement by 9.9 per cent.

General

Analysis of the performances of numerous representative railways disclosed that in spite of marked differences in the relations of expenses in primary accounts to total M.W.&S. the "effect of use" does not materially differ from the average of 33.13 per cent developed for all Class I Roads. It is therefore apparent that the application of that per cent would be reasonably satisfactory under ordinary conditions and obviate the necessity for the detailed work required for its development on the individual line.

Co-ordinated application of principles and methods presented in the foregoing discussion of the several phases of the problem is illustrated by example in Exhibits A and B.

Appendix A

EXAMPLE SHOWING METHOD OF ESTIMATING MAINTENANCE EXPENSES RESULTING FROM INCREASED PROPERTY AND INCREASED USE

Assumed Data

Property Maintained:	Base Period	Comparison Period
Tracks—First main, miles	100	110
Other main, miles	80	90
All other tracks, miles	30	40

Other than Track:

Bridges—Investment increase over Base Period		$ 85,000
Reproduction cost at B. P. prices	$ 505,000	....

(For complete solution it would be necessary to set up similar data for all other property accounts. Bridges used here for illustration of method.)

Traffic Handled Over Maintained Mileage:

	Base Period	Comparison Period
Gross ton-miles of cars and lading	12,000,000	16,000,000
Gross ton-miles of passenger locomotives	4,000,000	4,800,000
Gross ton-miles of freight locomotives	3,000,000	3,600,000

Maintenance Expenses (Normal):

Superintendence	$ 20,000
Ties	54,000
Rail	11,000
Other track material	16,000
Ballast	7,000
Roadway maintenance	38,000
Tracklaying and surfacing	91,000
Sub-Total—Track	$ 237,000
Bridges, Trestles and Culverts	10,100
All other expenses; which would be set up by Accounts in complete study	$ 103,900
Total M.W.&S. Expense	$ 351,000

Price Factors: (Relative to prices of 1914 as 1.00)

	Base Period	Comparison Period
Superintendence	1.15	1.70
Ties	1.18	1.95
Rail	1.10	1.54
Other track material	1.15	1.90
Ballast	1.20	2.16
Track labor	1.25	2.50
Bridges	1.21	2.06
All other items—to be set up in detail (say)	1.21	2.06

SOLUTION OF PROBLEM

I. Develop Factors for Increased Property:

A—Track

		Equated Track-mile Plan Miles of Track Maintained			
		Base Period		*Comparison Period*	
Kind of Track	*Equation Factor*	*Actual*	*Equated*	*Actual*	*Equated*
First main	1.00	100	100	110	110
Other main	0.80	80	64	90	72
All other tracks........	0.50	30	15	40	20
Totals....................		210	179	240	202

Factor for Increase: 202 divided by 179 = 1.13

B—Property Other Than Track

The example given in the text of this report (Sect. I-B Investments—structures) would be followed in deriving factors for increases in all property units other than Way. This shows that for the account Bridges assumed in this problem the factor would be 1.087.

II. Develop Factors for Increased Use:

A—Traffic Increase

		Traffic Units over Maintained Mileage			
		Base Period		*Comparison Period*	
Item	*Equation Factor*	*Actual*	*Equated*	*Actual*	*Equated*
Gross ton-miles of	(*a*)	(*b*)	(*a*) × (*b*)	(*c*)	(*a*) × (*c*)
Cars and lading......	1.00	12,000,000	12,000,000	16,000,000	16,000,000
Passenger locomotives	3.00	4,000,000	12,000,000	4,800,000	14,400,000
Freight locomotives..	2.00	3,000,000	6,000,000	3,600,000	7,200,000
(a) Total...........		19,000,000	30,000,000	24,400,000	37,600,000
(b) Total equated track miles maintained (I-A)			179		202
(c) Equated gross ton-miles per mile (a/b)			167,600		186,100
(d) Ratios of traffic density			1.00		1.11
(e) Per cent increase in USE					11.0%

B—Per Cent of Effect and Factors for Use by Accounts

	M.W.&S. Accounts	*Per Cent Affected by Use* (*a*)	*Per Cent Increase in Use* (*b*)	*Use Factor* (*a*) × (*b*) *plus* *1.00*
201	Superintendence	20	11.0	1.022
212	Ties	30	11.0	1.033
214	Rail	100	11.0	1.110
216	Other track material..............	100	11.0	1.110
218	Ballast	80	11.0	1.088
220	Tracklaying and surfacing.........	55	11.0	1.061
208	Bridges, trestles and culverts......	**10**	**11.0**	**1.011**

Note—Extend this table to include all accounts shown by Section II of Report to be affected by USE and from which values in Col. (a) are taken.

In the event of DECREASED USE, the factors for use become 1.00 minus (Col. (a) as above × Per Cent Decrease in Use).

III. COMPUTE MAINTENANCE ALLOWANCE FOR COMPARISON PERIODS:

	Base Period Expense Normal	Base Period Expense Equated to Comparison Period for Difference in					
		Prices		Property		Use	
		Factor	Amount	Factor	Amount	Factor	Amount
(a)	(b)	(c)	(d) = (b)x(c)	(e)	(f) = (d)x(e)	(g)	(h) = (f)x(g)
201 Superintendence	$20,000	1.48	$28,600	1.13	$ 33,448	1.022	$ 34,184
212 Ties	54,000	1.65	89,100	1.13	100,683	1.033	104,006
214 Rail	11,000	1.54	16,940	1.13	19,142	1.110	21,248
216 Other Track Material	16,000	1.65	26,400	1.13	29,832	1.110	33,114
218 Ballast	7,000	1.80	12,600	1.13	14,238	1.088	15,491
202 Roadway Maintenance	38,000	2.00	76,000	1.13	85,880	1.000	85,880
220 Tracklaying and Surfacing	91,000	2.00	182,000	1.13	205,660	1.061	218,205
Sub-Total-Track	237,000		432,640		488,883		512,128
208 Bridge Trestles and Culverts	10,100	1.70	17,170	1.087	18,664	1.011	18,869
All other accounts to be detailed ... say	103,900	1.70	176,630	*1.09	192,527	*1.017	195,800
Total M. W. & S. Expense	351,000	1.78472	626,440	1.1175	700,074	1.0396	726,797

Notes—

Col. (c)—Factors for price increases from Base to Comparison Period are derived from Assumed Data by dividing Comparison Period Factors by Base Period Factors.

Col. (e)—Factors for Track items are as derived from Equated Track-mile plan—factors for all other items derived separately and as indicated in preceding work sheet.

Col. (g)—Factors are as derived in preceding table.

*These factors have been assumed for purpose of completing the computation; they should be derived for the several individual accounts in the same manner as shown for Account 208, Bridges, Trestles and Culverts.

Appendix B

An alternate solution which would be satisfactory under ordinary conditions and involve considerably less computation, may be had by dealing with Total M.W.&S. Expense instead of the expenses in the Individual Accounts. Using same basic data as set forth in Appendix A this shorter solution is as follows:

(a)	Total M.W.&S. Expense at Base Period prices	351,000
(b)	Factor for increase in prices Base to Comparison Period	1.78472
(c)	Base Period Expense adjusted for Price Increase (a) × (b)	626,440
(d)	Factor for increased Property—using Equated Track-mile plan to indicate increase in both Way and Structures.	1.13
(e)	Base Period Expense equated for Price and Property (c) × (d)	707,877
(f)	Per cent increase in Traffic density	11.0
(g)	Per cent Total M.W.&S. Expense affected by Use, i. e. Average as per Table in Section II of Report	33.13
(h)	Factor for increased use 1.00 plus (f) × (g)	1.036
(i)	Base Period M.W.&S. Expense adjusted to Comparison Period for increases in Prices, Property and Use (e) × (h)	733,361

[5]THE COST OF STOPPING AND STARTING TRAINS

A method of estimating the cost of stopping and starting trains has been determined from an analysis of the expense items incident to train service that might properly be considered. These accounts and the basic factors by which they are related to the problem, together with detail discussion, tables, charts and examples are shown as Appendix A of Report of

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[5] Adopted Vol 28, 1927, pp. 475, 1319.

Committee XXI—Economics of Railway Operation, pages 473 to 512, Vol. 28 of Proceedings.

(A) WAGES OF TRAIN ENGINEMEN—Account 392
WAGES OF TRAINMEN—Account 401

(1) Wages of train and engine crews are not affected by train stops except when they are paid overtime rate. This is computed by multiplying the time lost in minutes, which includes the time lost in decelerating and accelerating and the time at stop, by the overtime rate per minute.

(B) FUEL FOR LOCOMOTIVES—Account 394

1. The amount of coal lost in making a train stop is dependent on the following:

(a) Coal required to restore kinetic energy in the train equivalent to the energy destroyed by the brakes in stopping.

(b) Difference in coal required by the stop and non-stop trains to do the work done by the non-stop train between the point at which stop train starts to decelerate and the point at which it regains the speed of the non-stop train.

(c) Coal consumed by the stop-train while standing at the stop.

(d) Coal required for the extra steam used by the stop-train in brake application, in all other auxiliaries, and that lost through the safety valves.

(e) Coal required due to the slipping of the drivers in starting and a decrease in furnace efficiency at same stops.

2. Stop losses referred to in paragraph 1 (d) being small and variable in amount, as compared to the total loss, may be included with the losses referred to in paragraph 1 (c). The total amount of such losses may be determined by formula (6), paragraph 5.

3. The amount of coal lost as described in paragraph 1 (a) is determined by formulas (1), (2) and (3).

Foot-pounds of energy destroyed by brakes

$$W = T(70V^2 + 20\ KDV^2 - DRV^2) = TV^2\ [70 + D\ (20K - R)] \quad \ldots\ldots(1)$$

Speed to which train must be accelerated to restore destroyed energy

$$S^2 = \frac{W}{70T} = \frac{V^2}{70}\left[70 + D\ (20K - R)\right] \text{ or}$$

$$S = .12V\ \sqrt{70 + D\ (20K - R)} \quad \ldots\ldots(2)$$

Pounds of coal required to generate energy required to accelerate train to S speed

$$A = \frac{W\ p'y}{1{,}000{,}000} = \frac{TV^2\ p'y}{1{,}000{,}000}\left[70 + D\ (20K - R)\right] \quad \ldots\ldots(3)$$

4. Foot-pounds of work done by both trains in overcoming the train resistance over the decelerating and accelerating distance of stop train.

$$w = T\left[1.16\ R\ M^3\left(1 \pm \frac{20G}{R}\right) + \left(70M^2 - \frac{W}{T}\right)\right]$$

$$= T\left[1.16\ R\ M^3\left(1 \pm \frac{20G}{R}\right) + 70\ (M^2 - S^2)\right] \ldots\ldots\ldots\ldots (4)$$

Difference in pounds of coal required by the stop and non-stop trains.

$$B = \frac{Ty}{1{,}000{,}000}\left[1.16\ RM^3p''\left(1 \pm \frac{20G}{R}\right) + 70\ p'''\ (M^2 - S^2)\right] \ldots (5)$$

5. Pounds of coal lost due to causes described in paragraph 1 (c) and (d).

$$C = xt \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

6. The total pounds of coal lost in stopping and starting freight train is then equal to the sum of the values $A + B + C$ in formulas (3), (5) and (6) and equal to

$$P = \frac{Ty}{1{,}000{,}000}\Big[V^2\ (p' - p''')\ (70 + 20DK - DR) + M^2$$
$$(70\ p''' + 1.16\ RMp'' \pm 23.2\ MGp'')\Big] + xt \ldots\ldots\ldots (7)$$

7. In formula (7) the term $20DK$ covers the approaching down grade effect on coal lost; on level track or up grade it is to be omitted. The term $23.2\ MGp''$ gives the departing grade effect on coal lost and where the acceleration of stop train is over level track this term becomes zero. The formula for level track is then

$$P' = \frac{Ty}{1{,}000{,}000}\Big[V^2\ (p' - p''')\ (70 - DR) + M^2\ (70\ p''' +$$
$$1.16\ RMp'')\Big] + xt \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Pounds of coal required to furnish 1,000,000 foot-pounds of energy at the drawbar at s speed

$$p' = 1.50 + .00011\ (25 - s)^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Difference in pounds of coal required to furnish 1,000,000 foot-pounds of energy at the drawbar at speeds of m and M

$$p'' = .00011\ [(25 - m)^3 - (25 - M)^3] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Difference in the pounds of coal required to furnish 1,000,000 foot-pounds of energy at the drawbar at $\frac{M + S}{2}$ and M speeds

$$p''' = .00011\ \left[\left(25 - \frac{M + S}{2}\right)^3 - (25 - M)^3\right] \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

In these formulas all cubical values are to be made positive, all other signs remaining unchanged.

8. Description of symbols used in the formulas:

A = pounds of coal required to generate energy required to accelerate trains to S speed.

B = difference in pounds of coal required by a stop train as compared with a non-stop train in generating the same amount of energy at their respective speeds.

Btu = British Thermal (heat) Units.

C = pounds of coal lost by the stop train while standing at the stop, including that required to replace energy lost by radiation, operating air pumps for maintaining air brake pressure and through the safety valves.

D = constant, which when multiplied by V^2 gives the distance traveled by the train after the initial brake application. Its value for different grades and train consist is given in Table 1.

G = per cent of average grade over the accelerating distance of stop train, and where substituted in formulas the down grade is to be given the negative value and up grade the positive value. All negative values of G greater than the maximum given by placing

$$G = \frac{70\ (M^2 \text{ or } V^2) + 1.16\,RM^3}{23.2\,M^3}$$

are made equal to the value thus given.

K = maximum per cent of down grade over the decelerating distance of stop train that will not supply excess energy. It is equal to the actual average per cent down grade traversed by the stop train between V and zero speeds whenever this average does not exceed the maximum per cent grade as given by the following formula:

$K = \frac{R}{20} + 3.5\left(\frac{M^2 - V^2}{DV^2}\right)$ (in which all negative values of $3.5\left(\frac{M^2 - V^2}{DV^2}\right)$ are made equal to zero).

M = speed in miles per hour of the non-stop train equal to the permissible operating speed or the average speed maintained over that part of the road by trains similar to the stop train.

P = total pounds of coal lost in stopping and starting freight trains on any grade.

P' = total pounds of coal lost in stopping and starting freight trains on level grade.

R = pounds of car resistance per ton of train back of the locomotive and tender; it is equal to 3.82 for trains averaging 50 tons or over per car, 6.0 for trains averaging under 50 tons per car.

S = speed to which train must be accelerated to restore destroyed energy.

T = total weight in tons of the stop train back of the locomotive and tender.

V = speed in miles per hour at which the initial brake application is made on stop train.

W = total foot-pounds of energy destroyed by the brakes of the stop train.

Z = reference symbol. See charts and tables, pages 488-512, Vol. 28 of Proceedings.

a = square feet of grate area of locomotive.

g = average actual decelerating down grade between point of brake application and zero speed. See charts, pages 489-512, Vol. 28 of Proceedings.

m = average speed of train in accelerating to M speed. Values for m are given in Table 2.

p' = pounds of coal required to furnish 1,000,000 foot-pounds of energy at the drawbar at s speed.

p'' = the difference in pounds of coal required to furnish 1,000,000 foot-pounds of energy at the drawbar at speeds of m and M.

p''' = the difference in pounds of coal required for furnishing 1,000,000 foot-pounds of energy at the drawbar at the speeds of $\frac{M+S}{2}$ and M.

s = average speed of train in accelerating to S speed. Values for s are given in Table 2.

t = time train stands at stop in minutes.

w = foot-pounds of work done by the stop train and non-stop train in overcoming the train resistance over the decelerating and accelerating distance of stop trains.

x = constant, the value of which has been determined to be .10 per square foot of locomotive grate area for all atmospheric temperatures of 40 degrees Fahr. or over, and .115 per square foot of grate area for all atmospheric temperatures under 40 degrees Fahr.

y = constant reflecting decreases or increases in overall efficiency of the locomotive due to grade, or of a saturated locomotive as compared with a superheated locomotive. For grade effect on efficiency of superheated locomotives $y = 1 \pm .20G$ and for saturated locomotives $y = 1.23\ (1 \pm .20G)$. The pounds of coal required to produce energy is based on the use of coal having approximately 14,000 Btu; for other grades of coal

$$y = 1.23\ (1 \pm .20G)\ \frac{14{,}000}{\textit{Btu in coal used}},\ \text{for saturated locomotive}$$

$$y = (1 \pm .20G)\ \frac{14{,}000}{\textit{Btu in coal used}},\ \text{for superheated locomotive.}$$

TABLE 1

9.

Average per cent grade traversed by train in stopping after initial brake application	Values of D			
	Average weight of cars in train			
	50 tons and over		Under 50 tons	
	Brake application		Brake application	
	Service	Emergency	Service	Emergency
+ to — .25	3.000	.270	1.000	.090
— .25 to — .50	3.515	.316	1.165	.105
— .50 to — .75	4.030	.363	1.330	.120
— .75 to — 1.00	4.500	.405	1.500	.135
— 1.00 to — 1.25	4.995	.450	1.665	.150
— 1.25 to — 1.50	6.490	.584	1.830	.165

NOTE.—+ = up grade and — = down grade. All curvature to be used as equivalent up grade, each degree of curvature being equal to .04 per cent grade.

TABLE 2

M or S speeds in M.P.H.	*m speed in M.P.H.*	*s speed in M.P.H.*
0 to 5	.63M	.63S
5 to 10	.65M	.65S
10 to 15	.72M	.72S
15 to 30	.73M	.73S
30 to 50	.75M	.75S

10. From various stops made with high speed Mikado engines it was found that the average time lost in decelerating and accelerating combined was as follows:

Trains consisting of empty cars on level track..4.0 minutes
Trains consisting of loaded cars on level track.4.1 minutes

This time increased on up grade and decreased on down grade at the rate of 12 seconds per one per cent of grade. Other types of locomotives would most likely give a different average time lost.

11. In addition to the time lost in decelerating and accelerating a period of 2 to 5 minutes will always be lost on account of time required to release the air, depending on the number of cars in a train. Good practice, which will eliminate brake-sticking, break-in-twos, etc., requires the enginemen to consume the amount of time in releasing their air, as follows:

25 car train, 2 minutes
50 car train, 3 minutes
75 car train, 4 minutes
100 car train, 5 minutes

(C) WATER FOR TRAIN LOCOMOTIVES—Account 397

1. Water for train locomotives will be increased with the number of train stops in the same proportion as the fuel is increased. Approximately one gallon of water is discharged at the water station for each pound of coal fired in the locomotive boiler. The amount and cost of water lost on account of train stop may be computed after determining the number of pounds of coal lost by the method described in Section B and multiplying by the average cost of water for the engine district.

(D) LUBRICANTS FOR TRAIN LOCOMOTIVES—Account 398

1. The expense chargeable to lubricants for train locomotives will increase with the number of train stops in approximately the same proportion as the number of train hours between terminals will be increased. The amount may be estimated by multiplying the time lost due to the stop by the cost of lubricants for train locomotives per train hour for the class of service involved.

(E) OTHER SUPPLIES FOR TRAIN LOCOMOTIVES—Account 399

1. The expense chargeable to other supplies for train locomotives will increase with the number of train stops as approximately 30 per cent of the items making up this account, including ice, oil for headlight, signal lamps and torches, sand and torpedoes, will be affected, depending upon the atmospheric temperature, the time of day or night the train stop is made, and other operating conditions. It is assumed that the number of train stops will be proportional to the number of train hours between terminals, and therefore the cost chargeable to this account will also be proportional to the increased number of train hours between terminals caused by train stop. The amount is estimated by multiplying the time lost account of stop by 30

per cent of the cost chargeable to Account 399 per train hour for the cost of train service involved.

(F) TRAIN SUPPLIES AND EXPENSES—Account 402

1. The amount chargeable to train supplies and expenses will not be affected by the number of train stops made between terminals.

(G) LOCOMOTIVE REPAIRS—Account 308; LOCOMOTIVE DEPRECIATION—Account 309; LOCOMOTIVE RETIREMENTS Account 310

(Including Interest on Investment)

1. The value of a locomotive is equivalent to the cost of ownership or the rental cost in case it is necessary for the operating company to hire a locomotive to perform any given service. The cost of ownership may be determined, based on—

Repairs, Interest, Depreciation and Retirements

by dividing the sum of the interest on the depreciated value of serviceable locomotives at 5¾ per cent per annum and the total of accounts 308, 309 and 310 for a representative period by the number of serviceable locomotives. This result may be reduced to a unit showing the cost of ownership per pound tractive effort per locomotive. In the event there is a surplus of power then the total cost of ownership should be multiplied by the ratio of the cost of repairs to the total, thus eliminating the cost of interest, depreciation and retirements.

(H) FREIGHT TRAIN CARS—REPAIRS—Account 314; FREIGHT TRAIN CARS—DEPRECIATION—Account 315; FREIGHT TRAIN CARS—RETIREMENTS—Account 316

1. The cost of freight train car repairs, depreciation and retirements account of train stop may be based on either the cost of ownership or the cost of car hire in the same manner as locomotive repairs, depreciation and retirements outlined in Section G. Per diem at $1.00 per day may usually be applied to the car delay in estimating this cost. In the event that there is a surplus of cars then the total cost of ownership should be multiplied by the ratio of the cost of repairs to total, thus eliminating the cost of interest, depreciation and retirements.

COMMITTEE XXII

ECONOMICS OF RAILWAY LABOR

[1]PLANS AND METHODS FOR OBTAINING RAILWAY LABOR

(1) The problem of obtaining railway labor is broad and one deserving of careful consideration and organization.

(2) In the interest of efficiency and economy, maintenance employees should have the necessary mental and physical qualifications.

(3) Best results may be obtained by providing some officer or some organization to supervise the selection and care of employees.

(4) The living conditions of employees should be sanitary and comfortable. Food should be wholesome and of sufficient quantity, and work so regulated as not to be injurious to health.

(5) Every encouragement, consistent with economy and efficiency, should be given to permanent employment throughout the year.

(6) To avoid abuses, free transportation for railway labor should at all times be within the control of regularly delegated officers or employees.

[2]TRAINING AND EDUCATING ENGINEERS IN THE ENGINEERING DEPARTMENT IN MAINTENANCE WORK

(1) Engineers trained in maintenance work are essential to an efficient organization.

(2) The systematic training of young engineers for maintenance work should be carefully undertaken, and if in due course they do not display necessary qualifications to combine practical and technical training with ability to organize, direct and supervise work, they should not be retained in this branch of service.

(3) Training of young engineers in maintenance work may best be accomplished by rotation in service.

(4) It is essential to the training of young engineers that they familiarize themselves with the rules and practices of the Operating and Accounting departments.

(5) In the interest of an efficient organization it is desirable to maintain a fixed minimum engineering force throughout the year.

(6) It is desirable that there be practical coöperation between railway managements and schools and colleges offering technical courses for the better preparation of young engineers entering railway service.

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[1] Adopted, Vol. 23, 1922, pp. 672, 1036.

[2] Adopted, Vol. 23, 1922, pp. 678, 1043.

[3]TRAINING AND EDUCATING EMPLOYEES (OTHER THAN ENGINEERS) IN THE MAINTENANCE OF WAY DEPARTMENT, LOOKING TO GREATER ECONOMY AND EFFICIENCY AS WELL AS PROMOTION

(1) A thorough and systematic method of training employees in maintenance work is essential for efficiency and for promotion to advanced positions.

(2) In promotion, merit and fitness should govern. Employees having necessary qualifications should be given every legitimate opportunity and encouragement to obtain necessary training and experience.

(3) To accomplish the best results, methods should be installed to promote individual effort and interest. Personal contact and personal interest shown on the part of the supervisory forces will go far to bring this about.

(4) Employees should be encouraged to seek further education from outside sources on general principles of railway operation, such as through correspondence, night schools and periodicals on railway subjects and membership in railway clubs and associations.

[4]METHOD FOR OBTAINING AND HANDLING RAILWAY EMPLOYEES

(1) In order to retain satisfactory employees, railway managements should provide means for the fullest possible coöperation between employer and employee, arranging for the education of all employees and particularly those in a supervisory capacity in the aims of the companies to secure that result.

(2) Where roads are of sufficient size to warrant the creation of a Personnel Department, we recommend that such a department be established whose duties shall be the encouragement of employees and their handling without prejudice, in their (a) employment, promotion and transfer; (b) education, training and service, including separation from service. On smaller roads work of the character above outlined should be assigned to some officer in the existing organization, to be handled independently of his relation to any particular department.

(3) The adoption of a plan of employee representation in railway work will, through the improvement of the spirit of coöperation, serve largely to stabilize labor and reduce the problem of obtaining new employees.

(4) The extension of benefit associations providing insurance against the hazards of sickness, accident, superannuation and death is essential to the development of a loyal and co-operative spirit in railway organizations, which is needed to assist in the work of stabilizing labor and render it more efficient and economical. Savings funds and loan provisions placed at the disposal of all worthy employees are an added incentive of merit and of economic value.

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[3] Adopted, Vol. 23, 1922, pp. 679, 1043; Vol. 28, 1927, pp. 284, 1313.

[4] Adopted, Vol. 25, 1924, pp. 757, 1364.

(5) The promotion of the mutual interests of employers and employees through participation in the ownership of the industry on which they are dependent for their income in wages or dividends is an objective greatly to be desired and warrants the careful consideration of the railways as a means of stimulating coöperation in the common objective.

(6) Plans for the establishment of satisfactory working conditions, including the provision of sanitary and agreeable facilities while on duty, comfortable rest-houses, rest-rooms and dining-rooms, maintained in cleanly condition, and service of a sufficient quantity of wholesome food, should be in effect on all roads.

(7) The establishment of standards and units of measure for all work performed which is susceptible of measurement, is a fundamental basis of harmonious understanding between employer and employee and the foundation for economical and efficient handling of labor.

[5]STABILIZATION OF EMPLOYMENT IN THE MAINTENANCE OF WAY DEPARTMENT IN THE INTEREST OF EFFICIENCY

(1) The equalization of expenses permits work to be done at the most economical time, seasonal and traffic conditions considered. It also prevents the distortion of operation ratios, while by its application more uniform forces may be employed in maintenance of way work, thereby tending toward stabilization of forces.

(2) In consideration of the ultimate economy of building a strong personnel of labor forces and the immediate economy of holding experienced men in maintenance of way service, as much work as is economically possible should be done in the winter, thus stabilizing forces.

(3) Minimum cost is secured through uniform production; reductions in manufacturing costs are directly reflected in prices charged the railway; stabilization of forces with the resulting increase in the uniformity of use of materials will lead to savings in the cost of materials over and above the savings effected directly through the increased efficiency of the forces.

[6]STANDARD METHODS FOR PERFORMING MAINTENANCE OF WAY WORK FOR THE PURPOSE OF ESTABLISHING UNITS OF MEASURE OF WORK PERFORMED

(1) The making of time studies and the comparison of performances of an individual gang with a standard, increases the efficiency of the gang under observation and of other gangs which are made acquainted with results.

(2) The general use of standard methods and units of measure of performance on divisions and districts of a railway has resulted in increasing the efficiency of track forces.

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[5] Adopted, Vol. 28, 1927, pp. 285, 288, 1315.

[6] Adopted, Vol. 23, 1922, pp. 680, 1045; Vol. 25, 1924, pp. 789, 1365.

The plan herein outlined and supplemented by the examples for illustrating its application, is based on the fundamental principles of good management.

It is a well-defined plan for maintaining contact with and directing the work of a class of labor which, by reason of the extended territory over which it is spread, is usually isolated and remote from that close supervision and direction so necessary to economic results.

It places available each day an accurate record of the performance of each gang, with its rating according to the established units of measure, for the use of the supervising officer in directing effort to increase the effectiveness of the gangs.

(1) Standard Methods and Time Schedules for Each Item of Work

Examples of typical methods and schedules are given as:

Exhibit A—Method—Making Time Studies.
B—Method—Renewing Rail Out of Face.
B-1—Schedule—Renewing Rail Out of Face.
C—Method—Cross-Ties—Renewing.
C-1—Schedule—Cross-Ties—Renewing.

(2) Instructions to Foremen to Enable Them to Submit Accurate Reports of Performance

An example of typical instructions is given as:

Exhibit D—Instructions for Reporting and Distributing Track Work Time Charges.

(3) Closer Supervision by Means of Planning and Dispatching the Work in Advance

Examples of typical forms are given as:

Exhibit E—Planning Sheet.
F—Work Order or Dispatching Sheet.

(4) Sample Forms for the Notation of Records and Performance for Comparison of Results

Examples of typical forms are given as:

Exhibit G—Daily Record of Track Work Performance.
H—Monthly Record of Track Work Efficiency.

Taking up these various features in order:

(1) STANDARD METHODS AND SCHEDULES

Standard schedules, or units of performance, should be established with great care, as it is essential that they be correct and that the organization of the gang and method of doing the work are the best that can be worked out.

The standard performance, or 100 per cent efficiency, is the output of a first-class gang working at a speed which can be continuously maintained without physical harm to the men, following an approved method of doing the work and consisting of the most effective number of men for the kind of work to be done.

To arrive at the 100 per cent standard, first-class gangs are to be selected and detail time studies made of the performance, the time studies being divided into as many moves and as much detail as possible in order that the various studies may be compared in detail and a standard method worked out which will eliminate all unnecessary moves. If it appears that an improvement can be made, the organization of the gang and the method of doing the work should be altered and new studies made. When the most satisfactory organization and method has been found, a final detail study is made of the performance of the gang and this is established as 100 per cent efficiency and issued as a standard schedule. In this way schedules may be established for all of the more important items of maintenance work. A "Method for Making Time Studies" and a sample "Time Study Sheet" are shown in Exhibit A.

In preparing such schedules it may at first be thought that, owing to the wide variation in conditions, there would be a number of items of work for which it would be impossible to work out standard schedules, but the study of performances will develop a remarkable uniformity in the output of gangs working under apparently widely varying conditions, and there are relatively few items of maintenance work which cannot be standardized. In cases where one standard schedule cannot be made to apply, as, for example, in ditching, a schedule should be made for the individual job and be based on previous records, performances under similar conditions, or observations after the work is started. For individual pieces of work of this kind, after careful study and planning of a method to be followed, a schedule or standard of output for 100 per cent efficiency should be established and the foremen's reports graded on this basis.

Going to and from work and clearing the track for passing trains, represents considerable lost time which is beyond the control of the foreman and men. This lost time is classed as detention, and studies should be made to determine the amount of detention for each gang. This detention is expressed in per cent of total time and, in grading the foreman's reports for comparison with the standard schedule, a credit of the detention per cent is allowed. On terminal and yard sections the detention is usually much more than on road sections.

(2) INSTRUCTIONS TO FOREMEN

To form an accurate comparison of the performance of the various gangs, uniformity in the reports submitted by the foremen is necessary. Owing to the difficulty some foremen have in making reports, it is desirable to have all forms used by them as simple as possible.

A daily report by the foreman of time spent and the work done by each gang is necessary. Where there is in use a form of daily time report, it can readily be made suitable for this purpose.

It is, however, necessary that the distribution shown on the daily time report be made with care, so that each item of work can be correctly graded. To secure this result detail instructions governing the distribution and reporting of the time charges are required.

Typical instructions for reporting and distributing track work time charges are given in Exhibit D.

(3) PLANNING AND DISPATCHING

To outline the order of the work and to assign it to the gangs to follow in sequence, so as to reduce the loss of time consumed by the unnecessary movement of the gangs from place to place, a system of planning and dispatching is needed.

Early in the year the program of work for the season should be decided upon and charted on a planning sheet (Exhibit E), the proposed work being shown in yellow. Thereafter as the work progresses, monthly planning sheets are prepared; the completed work is shown in green and the monthly program in red. A few days before the close of the month the Division Engineer calls a meeting of the supervisors for the purpose of planning the work for the month. The work to be done, the location and the relative order in which it is to be undertaken is decided upon and shown in red on the chart. The quantity of work to be accomplished is computed from the standard schedules and the force allotted for the month. The direction in which the work is to progress, the date on which it is to be commenced and the calculated date of completion are to be shown on the chart.

The chart is prepared in duplicate, one copy to be retained by the Division Engineer and the other for the use of the supervisor. Upon his return to headquarters, the supervisor transmits the program to the foreman by means of work orders, giving him the program for the entire month, or any part of it, as he may see fit. For this purpose a work order, or dispatch book, is provided (Exhibit F). The book is bound in stiffback, notebook form, and contains 100 perforated leaves.

The work order is made out in duplicate, the carbon copy being filed on the dispatch board, serving as a ready reference showing the work being done by each gang and where working. The work order states the kind, location, amount of work to be done and the time to be consumed. Upon completion of the work the foreman dates and signs the order and returns same to the supervisor. The foreman is given a work order for all work to be done. This, however, does not relieve him of the responsibility of making unforeseen and emergency repairs.

(4) FORMS AND REPORTS

For the purpose of recording the performance of the gangs two forms are used—one, a Daily Record of Track Work Performance (Exhibit G), the other, a Monthly Record of Track Work Efficiency (Exhibit H).

The result of each day's work as sent in by each foreman on the Daily Time Report is posted on the Daily Record Sheet, and the efficiency per cent of the day computed. For example: A gang of a foreman and nine men, working ten hours per day, holds a work order to renew ties without raising track. The schedule under which the work will be done is that given as an example of a Standard Schedule (Exhibit C-1), and is eight ties per ten hours. The foreman's daily report shows that his gang renewed 64 ties in 100 hours. The standard time required to renew 64 ties in stone ballast track not raised is 80 hours, whereas the actual time consumed was 100 hours. However, 10 per cent of this was consumed by clearing passing trains and other delays chargeable to "Detention," leaving 90 hours actually devoted to effective work. On the Daily Record Sheet, under the heading of Renewing Cross-Ties, 80 is recorded as "Standard Time" and 90 as "Actual Time," indicating an efficiency of 89 per cent. All other work is recorded in the same way.

At the close of the month the "Monthly Record of Track Work Efficiency" is compiled from the totals of the "Daily Record." The monthly record shows the percentage of efficiency made by every gang on each class of work, the average of every gang on all work, and the average for the supervisor's sub-division—in other words, a detailed and an accurate record of the actual performance of every gang as compared with the Standard Performance. The "Standard" divided by the "Actual" gives the efficiency per cent.

ADDITIONAL SUPERVISION REQUIRED

Supervisors should not be required to handle the details of the operation of this system as it is impossible for them to do so in addition to their regular duties. Each Supervisor should be given an assistant, who devotes his entire time to the study of standard schedules and methods, to the recording and study of performances, to the instruction of the foremen in regard to standard practice, and to checking in the field the reports of work done to guard against errors.

Exhibit A

METHOD FOR MAKING TIME STUDIES

Time studies are made: First, to find the proper time to allow as standard for any given piece of work; second, to find the best method of doing the work, as to number of men, organization, sequence of separate operations, proper tools, speed of work, etc. These features are all developed through analysis of the work, separating it into the different operations, timing each one separately several times, and considering the factors that make the quickest time possible.

Several time studies on each piece of work studied, are therefore necessary, as a single one may be misleading. The standard time is not the sum of the least time for all the operations, as in some instances these least times may represent some favorable conditions which only occur at long intervals or too strenuous work by the men for a short time, which could not be maintained continuously. The standard is the time in which the work to be performed can be done continuously by an industrious, trained and efficient gang.

In track work there are several different types of time studies:

1. When one man does the entire piece of work, as in Tightening Bolts.

2. When more than one man is required, a fixed gang is assigned and part are idle while the others work, as in Unloading Ballast from Hoppers.

3. Where more than one man is required, but where the working conditions are so elastic that no matter what size gang is provided, all the men can be worked, as in Laying Rail.

Case No. 1 is simple. The operations in a typical case being: (*a*) Preliminary Oiling, (*b*) Walking from one joint to the next, (*c*) Tightening each bolt in order, (*d*) Foreman's supervision. If the gang has but three or four men, the Foreman should work like the others when tightening bolts and no time be added for Foreman's supervision.

Case No. 2. The work train is a factor in the example described and a gang is usually detached for the work and sent with the train, hence, if delayed, the men are idle. In order not to delay the train the gang should be as large as can work effectively; if larger, a decided waste results, for the reason that the working space is restricted.

Under each operation the items of work which go on simultaneously are noted with the number of men engaged in each (see Sample Time Study, Exhibit A). The sum of the identical times used for each operation, except Foreman's time, equals the elapsed time, and the proposed elapsed time multiplied by the standard gang (including Foreman) equals the proposed standard time.

The Sample Time Study shows that 10 men were used but that it was seen 4 men on ground and 4 on cars would be ample and an 8 man gang was recommended. It will be noted that the standard times shown are not the lowest or the highest but are chosen as representing a good lively performance.

Case No. 3 is simple although the gang is larger. When a squad of men finishes one operation they are put on another and all may be kept busy if the Foreman and his assistants are capable.

The final standard time is made up of several simple time studies for, (*a*) Adzing, (*b*) Drawing spikes, (*c*) Lining out old rail, (*d*) Turning in new rail, (*e*) Placing joints, (*f*) Full bolting, (*g*) Full spiking.

As to each separate individual operation, the following questions should be decided before setting the proposed standard time:

1. Is the operation necessary?
2. Is it done in the best way?
3. Is it done in the least time consistent with continuous performance?

(Sample Time Study Sheet)

TIME STUDY ON UNLOADING STONE BALLAST FROM HOPPERS

Made on.............Division, Section 60, at....................., by J. Doe, date April 6, 1916; size of gang 10* men, 1 Foreman; weather, fair and cool.

Note: Quality of Workmanship.	Speed of Performance.
Average ....X....	Average ....X....
Better than average........	Faster than average............
Poorer than average........	Slower than average............

Note if there was any idle time.
Give recommendation as to standard size gang.
Note any interruptions.

Operation No.	ITEMS OF WORK.	TIME STUDY No. 1.	TIME STUDY No. 2.	TIME STUDY No. 3.	PROPOSED STANDARD TIME.
1		10:10 a. m.	10:21 a. m.	10:32 a. m.	
	Placing shoes..........	2 min., 2 men	1½ min., 2 men	2½ min., 2 men	2 min., 2 men
	Removing shoes from empty...............	2 min., 2 men	1½ min., 2 men	2½ min., 2 men	2 min., 2 men
	Waiting to shovel down	2 min., 6 men	1½ min., 6 men	2½ min., 6 men	2 min., 4 men
2	Placing tie.............	2 min., 2 men	3 min., 2 men	1½ min., 2 men	2 min., 2 men
	Removing tie from empty...............	2 min., 2 men	3 min., 2 men	1½ min., 2 men	2 min., 2 men
	Waiting to shovel down	2 min., 6 men	3 min., 6 men	1½ min., 6 men	2 min., 4 men
3	Releasing drop bottoms	3 min., 4 men	2½ min., 4 men	5 min., 4 men•	3 min., 4 men
	Winding up drop bottoms (empty).......	3 min., 4 men	2½ min., 4 men	5 min., 4 men	3 min., 4 men
	Waiting to shovel down	3 min., 2 men	2½ min., 2 men	5 min., 2 men	....
4	Shoveling down.......	4 min., 6 men	4½ min., 6 men	3½ min., 6 men	4 min., 4 men
	Jarring down ballast (by men on ground)..	4 min., 4 men 10:21 a. m.	4½ min., 4 men 10:32 a. m.	3½ min., 4 men 10:45 a. m.	4 min., 4 men
	Foreman's Time.......	11 min., 1 man	11 min., 1 man	13 min., 1 man	11 min., 1 man
	Elapsed Time.........	....	....	....	11 min., 9 men
	Proposed Standard....	....	....	....	99 min.

* Recommend 8 men for this work.

• Delay by drop bottom sticking.

Exhibit B

SCHEDULE: RAIL—RENEWING OUT OF FACE

The method outlined will be for the simplest conditions, *e. g.*, light curvature, no tie plates, new rail of same or heavier section, and both new and old rail laid with plain angle bars.

Special conditions varying from the above can be met by changing the organization to meet their needs.

The work preliminary to rail relaying consists of:

(*a*) Scoring or preliminary adzing to enable spikes to be drawn more readily.
(*b*) Drawing every third spike on one side.
(*c*) Starting the remaining spikes.
(*d*) Driving down stubs.
(*e*) Removing anticreepers.
(*f*) Driving tie plugs.
(*g*) Rough adzing.
(*h*) Setting up rail.

The above should be done the first thing in the morning and the organization should be as given below.

A typical organization is given for a 32-man gang, and another typical organization for a 22-man gang. Where labor-saving devices are used, the gang organization should be modified to adapt it to the most efficient use of such device.

TYPICAL GANG ORGANIZATION FOR WORK PRELIMINARY TO RAIL LAYING,

32-MAN GANG

2 Men adzing around spikes to be drawn.
6 Men with claw bars drawing every third spike on outside of rail and starting remaining spikes on outside.
1 Man driving down stubs.
2 Men driving tie plugs every third spike.
4 Men rough adzing outside of rail base.
1 Man with small bar turning rail up for tong men to pick up.
12 Men with rail tongs picking up new rail and placing it on end of ties.
1 Man with small bar turning rail down on ties with head of rail toward and about 8 inches from the rail to come out.
1 Waterboy.
2 Foremen.

32 Men.

METHOD AND DISTRIBUTION OF GANG FOR PRELIMINARY WORK

The work is started by the adze-men cutting around the spikes. They are followed by the claw bar men, who should be spaced one man to a rail and instructed to pull every third spike on the outside of the rail and start the remaining outside spikes so that they may be readily pulled when the track is opened. Each man on completing work on the rail assigned him should move to the sixth rail ahead and continue drawing every third spike and starting the remaining spikes. This space interval should be maintained continuously.

Following the claw bar men, one man drives down the stubs of any spikes which may have broken and removes anticreepers from old rail, two men plug the old spike holes in every third tie. Four men immediately follow doing all necessary rough adzing to save time of adze-men who level rail seat after old rail is turned out.

Working about opposite the adze-men, one man with a small bar turns up the new rail on its base so that it may be readily picked up by the tong men. Following the adze-men, twelve men with rail tongs pick up the new rail and place it on its base on the ends of the ties, one man with a short bar turns the rail down on its side so that the head of the new rail is towards and about 8 inches from the rail to come out.

One Foreman should supervise the work of the claw bar men, adze-men, etc., and the other, work of the tong men. One water boy supplies the entire gang.

The rail must be placed on the end of ties with care and accuracy; the end of the first rail so placed must be exactly opposite the end of the last new rail laid. On tangents an allowance for expansion should be made about every fifth rail. On the outside rail of curves additional spacing is necessary in setting up the new rail, whereas on the inside rail an occasional lap to be allowed on curves depends on the degree of curvature.

The above organization should do all preliminary spike pulling and set up from 225 to 230 rails before 10.00 a. m.

The preliminary work having been completed the organization of the gang is changed to meet the requirements for laying the new rail. The following is the gang organization for 32-men gang:

3 Men with claw bars pulling remaining spikes on outside of rail.
1 Man pushing truck loaded with tools, etc.
2 Men throwing out old rail.
2 Men driving tie plugs.
3 Men adzing and cleaning rail seat, after assisting in starting out old rail.
2 Men with claw bars starting inside spike after old rail is thrown out.
2 Men turning new rail to place and applying expansion shims.
1 Man holding new rail to inside spikes for spiking.
1 Man tacking three spikes per rail.
2 Men putting on angle bars and starting one bolt with fingers.
4 Wrench men putting in and tightening two bolts to each joint.
4 Spikers driving at least every other spike.
1 Water boy.
2 Flagmen.
2 Foremen.
—
32 Men.

METHOD AND DISTRIBUTION OF GANG FOR LAYING THE RAIL

Traffic in both directions must be protected by flagmen as prescribed in the Book of Rules.

Three men with claw bars pull the remaining outside spikes, each man taking one rail length, upon the completion of which he moves to the third ahead and continues pulling all outside spikes. As soon as a joint has been removed, the spikes pulled for three rails, nine men equipped with bars, commence throwing the old rail out over the new rail. When one rail length has been thrown out the weight, overhanging the new rail, assists in throwing out the old rail to such an extent that two men can continue the work and the others are divided as follows: Two men drive tie plugs in remaining spike holes; three men finish adzing and clean rail seat; two men with claw bars start inside spikes after old rail is thrown out, lifting them a sufficient distance to readily admit the base of the new rail.

Two men roll rail into place by means of small bars inserted in the bolt holes. The men work at opposite ends of rail; the man at the rear end of the rail rolls the rail over so that the base of rail is toward the center of the tracks; the man at the front end of the rail is in the direction of laying, then gives it another turn so that the rail stands on its base just outside of the inside of spikes. The rear man carries a small bucket containing 25 or 30 expansion shims, and as soon as rail is in place inserts shim while front man with bar forces rail back to contact with shim. Two men follow, one with bar holds the rail close to the inside line of spikes while the other tacks it in place with spikes at the center and quarter points.

The rail now being in the proper position in track, two men place the angle bars and insert the end bolts in the direction of traffic, the nut being run on the finger threads only. Four wrench men follow applying one more bolt per joint and tightening all bolts applied. If four hole angle bars are used the preliminary bolts should be numbers one and three in the direction of traffic and in six hole angle bars numbers one and four in the direction of traffic. The wrench men are followed by four spikers driving spikes in two of every three ties.

The gang is preceded by one man with push car containing surplus tools, bolts, nutlocks, compromise joints, etc.

One water boy supplies the entire gang and two Foremen supervise the work. The run having been completed and track closed the entire gang drops back on full bolting and spiking.

The above gang if given the track for an hour or more should average 75 rails per hour. For a period of 30 minutes, the gang should average a rail a minute. For any period less than 20 minutes, it is not advisable to open the track unless the work is being done in a congested district, in which case it may be necessary to break the track for a period less than 20 minutes.

ORGANIZATION OF GANG FOR OTHER CONDITIONS

To meet other conditions than those outlined above additional men must be added to the gang. All special conditions and combinations of various type of joints, etc., cannot be covered by illustrations; those commonly met with are given below.

Example No. 1 is that described in detail above and is the basic gang for two Foremen and 30 men.

Example No. 2. If the new rail is laid with Continuous joints add two men for additional joint adzing. Total gang, two Foremen and 32 men.

Example No. 3. Should the old rail coming out be laid with Continuous or depending flange joints, add two men for throwing out old rail at joints, and for Continuous or Weber joints, add one man for shimming old joint ties. Total gang, two Foremen and 33 men.

Example No. 4. If any type of depending flange joint is used on the new rail, add one Foreman and 20 men to respace and tamp joint ties. Total gang, three Foremen and 50 men.

Example No. 5. If old rail is tie-plated and new rail of a heavier section, requiring the renewal of all tie plates, add two Foremen and 30 men, which would make a total of four Foremen and 60 men.

The gang organization shown above may be combined in any way to meet the varying conditions outlined.

Under some combinations of conditions, the gang required becomes too large to be handled as a single rail gang. When this occurs the gang should be split up into smaller individual gangs. If, for instance, conditions are as shown under Examples 4 and 5, gang required would be five Foremen and 80 men, which would be difficult to handle and should be divided into smaller independent gangs.

For the purpose of describing the method, it has been assumed that the outside line of spikes will be pulled and the inside will remain; the method, however, applies just as well when the inside line of spikes is pulled and the outside line remains.

TYPICAL GANG ORGANIZATION FOR 22-MEN GANG

PRELIMINARY

1 Man adzing around spikes to be drawn.
3 Men with claw bars drawing every third spike on outside and starting remaining spikes on outside.
1 Man driving tie plugs.
1 Man turning rail for tong men.
12 Men with rail tongs.
1 Man turning rail to place on ends of ties.
1 Man distributing bolts, nut-locks, spikes and tie plugs.
1 Water boy—assisting adzer.
1 Foreman.

—

22 Men.

Exhibit B-1

SCHEDULE: RAIL—RENEWING OUT OF FACE

TIME DISTRIBUTION BASED ON TEN RAILS, SIX HOLE PLAIN BARS REPLACING FOUR OF SIX HOLE PLAIN BARS

OPERATION No.	OPERATION.	MINUTES FOR 10 RAILS.
1	Adzing before drawing spikes	43
2	Setting up rail	90
3	Drawing one line of spikes	90
4	Lining out old rail	60
5	Plugging spike holes	25
6	Adzing	50
7	Cleaning rail seat	18
8	Driving down stubs and cracking up remaining spikes	18
9	Turning in new rail	28
10	Distributing bolts, nut locks and spikes	20
11	Placing splice bars, and full bolting	140
12	Full spiking	110
13	Uncoupling old rail	110
	Two flagmen during runs	84
	Water boy—one for gang of twenty men	44
	Foreman—one for gang of twenty men	44
	Total time for ten rails	974
	Total minutes for one foot	2.95
	Standard Schedule, Hours per 33-ft. Rail	1.623

If any of the above items are not performed, subtract corresponding time with an allowan or supervision from totals and figure revised standard time.

SPECIAL CONDITIONS

Use of Angle Bars with Depending Flanges:

A—If respacing of ties is necessary on this account, grade the work by Schedule for Tie Respacing, counting each tie as one-half tie, if but one end of the tie is moved.

B—No additional time except what is described above is to be allowed for laying rail with depending flange joints.

C—When rail being *replaced* has bars with depending flanges, add thirty minutes to above itemized schedule and

Standard Schedule, Hours per 33-ft. Rail will be: 1.673.

Use of Continuous Bars:

A—When rail is being laid with Continuous bars, add seventy minutes to above itemized schedule and

DURING RUN

2 Men with claw bars pulling remaining spikes.
2 Men throwing out old rail.
1 Man with claw bar starting inside row of spikes.
1 Man driving tie plugs and also driving down stubs.
1 Man cleaning rail seat and helping move rail longitudinally.
2 Men adzing.
1 Man turning in rail and getting expansion.
1 Man holding rail for spiker who tacks three spikes per rail.
1 Man spiking as above.
2 Men spiking two of every three ties.
4 Men applying joints with two bolts and tightening.
2 Flagmen.
1 Water boy, pushing truck with tools, etc.
1 Foreman.

22 Men.

DIRECTION OF LAYING

Rail should be laid with the current of traffic for the reason that the rail on curves is usually badly curve worn, and when it becomes necessary to make a connection on the high side of a curve there is a bad lip between the old and new rail which, for safety, should be in a trailing position.

MAKING CONNECTIONS

One of the quickest methods of cutting a rail for making connection is as follows:

The location of the cut having been determined, the old rail beyond this point should be full spiked. Score deeply the inside and outside of the base with a rail cutter, then place a claw bar between the webs of the two rails to give additional firmness. Men with bars line out old rail and hold in this position while one man with spike maul strikes the outside base. The rail will usually break at the first blow. Compromise joint is then applied and connection completed by full bolting and spiking.

Standard Schedule, Hours per 33-ft. Rail will be: 1.740.

Drawing a Second Line of Spikes:

If it is necessary to draw more than one line of spikes on one side, add ninety minutes to above itemized schedule and

Standard Schedule, Hours per 33-ft. Rail will be: 1.773.

Removing Anticreepers:

A standard time of .5 minute each will be allowed for removing anticreepers from rail.

Making Connections:

Add to the standard hours computed for laying the rail additional hours for making connections as follows:

For each connection one per cent of the total actual hours on rail laying reported for the day.

EXAMPLE

A gang of twenty men laying 100 rails in a day, and making four connections, where detention is ten per cent:

100 x 1.623	162
Four connections at .01 of 200 hours	8
Total standard hours	170
Total actual hours working	180
Total detention	20

Performance—95 per cent.

The only detention allowed will be that authorized for the section where the rail is being laid.

Exhibit C

METHOD: CROSS-TIES—RENEWING

TRACK RAISED—STONE BALLAST

If ballast is dirty it must be cleaned before track is raised.

After the first raise is made and all ties tamped, the gang begins to renew ties. First, spikes are drawn and sufficient cribbing out done to permit ties to be moved sidewise in crib and drawn out. Bed is then prepared and new tie is inserted, using tie tongs. It is held up till tamped, after which spiking follows. The schedule includes piling for burning, using pyramidal piles parallel to track containing not more than 15 ties. These ties should not be burned under signal or telegraph wires.

Before beginning tie renewal the Foreman will go over the new ties marking (1) those ties to be used under joints, (2) which side of tie is to be uppermost and (3) a line indicating where the outside base of the outside rail should come.

One man should be assigned to draw spikes on all ties to be renewed. The remainder of the gang should work in pairs, except in large gangs where different men may be assigned to the different operations.

GRAVEL OR CINDER BALLAST

Ties should be marked by Foreman as explained under "Track Raised —Stone Ballast." First, spikes are drawn on ties to be renewed. Then, when the track is raised with jacks, the old ties are left in their bed and drawn out with picks. New ties are placed, and when jack men have moved forward, the new ties are tamped while being held up against the rail. Spiking follows. Men work in pairs. In large gangs, different men may be assigned to the different operations.

TRACK NOT RAISED—STONE BALLAST

Before renewals the Foreman should mark ties as explained in "Track Raised—Stone Ballast."

First, sufficient ballast should be removed to allow old tie to be readily moved sidewise in crib, then drawn out. The bed is then prepared and new tie drawn in with tie tongs, after which tie is held up to rail and tamped under both faces of the tie to outer end of tie and eighteen inches inside of rail. Spiking follows.

Ballast is cleaned if dirty and returned to crib and the shoulder dressed. Men should work in pairs.

GRAVEL OR CINDER BALLAST

Method is same as for Stone Ballast, except that tamping is completed for full length of tie, men working opposite to each other.

Exhibit C-1

SCHEDULES: CROSS-TIES—RENEWING

TRACK NOT RAISED

OPERATION No.	OPERATION.	TIME DISTRIBUTION. MINUTES PER TIE. CRIBS FULL.			
		Stone Ballast		Gravel or Cinder Ballast	
		In Single or Outside Track.	Inside Track or as Noted Below*.	Main Track.	Side Track.
1	Cribbing out	18	27	10	6
2	Drawing spikes	3	3	3	3
3	Removing old tie	2	4	2	1
4	Preparing new bed	3	3	2	1
5	Carrying tie to place	2	2	2	2
6	Placing new tie	2	4	2	2
7	Applying two tie plates	1	1	1	1
8	Driving four spikes	4	4	4	4
9	Tamping	13	14	8	6
10	Replacing and dressing ballast	10	14	3	2
11	Carrying old tie and piling for burning	2	2	2	2
	Foreman, one-tenth of above time	6	8	4	3
	Total minutes for one tie, cribs full	66	86	43	33
	Standard Schedule, Hours per Tie, Cribs Full	1.1	1.43	.72	.55
	Total minutes for one tie, cribs ¾ full.	59	74	40	30
	Standard Schedule, Hours per Tie, Cribs ¾ Full	1.0	1.23	.67	.50
	Total minutes for one tie, cribs ½ full.	53	63	36	26
	Standard Schedule, Hours per Tie, Cribs ½ Full	.9	1.05	.60	.43
	Total minutes for one tie, cribs ¼ full.	42	56.50	32	25
	Standard Schedule, Hours per Tie, Cribs ¼ Full	.7	.94	.53	.42
	If stone ballast is dirty, cribs and shoulders should be thoroughly cleaned, forking all the stone. In that case the total times and schedules would be as follows:				
	Total minutes for one tie, cribs full	79	99	....	....
	Standard Schedule, Hours per Tie, Cribs Full	1.32	1.65	....	....
	Total minutes for one tie, cribs ¾ full.	66	81	....	....
	Standard Schedule, Hours per Tie, Cribs ¾ Full	1.00	1.35	....	....
	Total minutes for one tie, cribs ½ full.	55	65	....	....
	Standard Schedule, Hours per Tie, Cribs ½ Full	.92	1.08	....	....

* Use this schedule when additional cribbing out is necessary by reason of the existence of three or more tracks on close centers at same level or where there is an obstruction such as platform or wall.

Track Raised

OPERATION No.	OPERATION.	TIME DISTRIBUTION. MINUTES PER TIE. CRIBS ¾ FULL AFTER RAISE. Stone Ballast.	Gravel or Cinder Ballast.
1	Cribbing out	6	....
2	Drawing spikes	3	3
3	Removing old tie	1.5	1.5
4	Preparing new bed	2.5	2
5	Carrying tie to place	2	2
6	Placing new tie	2	2
7	Driving four spikes	4	4
8	Carrying old tie and piling for burning	2	2
	Foreman, one-tenth of above time	2	1.5
	Total minutes for one tie, cribs ¾ full	25	18
	Standard Schedule, Hours per Tie, Cribs ¾ Full	.42	.30
	Total minutes for one tie, cribs ½ full	21	17
	Standard Schedule, Hours per Tie, Cribs ½ Full	.35	.28
	Total minutes for one tie, cribs ¼ full	17	16
	Standard Schedule, Hours per Tie, Cribs ¼ Full	.28	.27

If tie plates are applied the above schedules become:

With Tie Plates

Standard Schedule, Hours per Tie, Cribs ¾ Full	.44	.32
Standard Schedule, Hours per Tie, Cribs ½ Full	.37	.30
Standard Schedule, Hours per Tie, Cribs ¼ Full	.30	.29

Exhibit D

INSTRUCTIONS FOR REPORTING AND DISTRIBUTING TRACK WORK TIME CHARGES

SINGLE OPERATIONS

Kind of Work.	Manner of Reporting.	Items To Be Included.
Lining— (Acct. 220-e)	State feet of track lined and whether main or side track...	Breaking down shoulder, lining track, replacing and dressing ballast.
Surfacing— (Acct. 220-e)	State total number of ties tamped and feet of track surfaced, whether tamping one or both ends of ties, number of faces, condition of cribs, kind of ballast and if main or side track........................	Cribbing out, tamping, replacing and dressing ballast.
Gaging— (Acct. 220-e)	State number of ties gaged, whether with or without adzing, and if main or side track..	Pulling spikes, plugging holes, adzing and respiking to gage.
Laying Rail— (Acct. 220-c)	State weight, amount laid in feet, whether new or repair and if laid in Main Track or Siding. State kind of joints on new and old rail, number of connections made; if any anti-creepers removed, state number. State time placing tie plates and numbers of plates. Make separate report of time distributing rail, new or repair and loading rail removed.........	Pulling spikes, lining out old rail, adzing, lining in new rail, putting on rail joints, full bolting, full spiking to gage, uncoupling old rail, trucking material, flagmen and water boy. Time consumed removing old tie plates and placing new plates to be reported separately. Separate report to be made of time consumed unloading rail to be laid and loading rail removed.
Replacing Broken and Defective Rail— (Acct. 220-c)	State weight, number of rails and length, whether new or repair, and kind of joints used. Show time trucking and distance trucked, whether on hand or push car, and number of flagmen used......................	Pulling spikes, lining out old rail adzing, lining in rail, putting on rail joints, full bolting, full spiking to gage and flagmen. If tie plates are changed make separate charge, also separate time consumed loading, unloading and trucking rail.
Replacing Rail Joints— (Acct. 220-d)	State number, kind of joint and number of holes..............	Removing old bolts and joint, placing new joint and full bolting.
Tightening and Replacing Bolts— (Tightening bolts Acct. 220-e. Replacing bolts Acct. 220-d)	State number of bolts tightened, number renewed and on which track.........................	Removing old bolts, putting in and tightening new bolts and tightening old bolts.
Renewing Cross-Ties— (Digging In) (Acct. 220-b)	State number of ties, with or without plates; kind of ballast; condition of cribs and whether main or side tracks. If trucking show number of ties, distance trucked, number of loads and number of flagmen used..........................	Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, tamping, refilling cribs, dressing ballast, carrying and piling old tie for burning, if less than 50 feet. If new tie is moved more than 100 feet or old tie is moved more than 50 feet, separate time consumed loading, unloading and trucking. If ballast is cleaned, the time consumed should be reported separately.

Exhibit D

SINGLE OPERATIONS—Continued

Kind of Work.	Manner of Reporting.	Items To Be Included.
Respacing Ties— (Acct. 220-b)	State number of ties, kind of ballast, condition of cribs and whether or not track is raised	Cribbing out, driving tie to place, tamping, replacing and dressing ballast. If respacing is done during raise, a portion of cribbing out, the tamping, and a portion of replacing and dressing ballast, should be charged to "Surfacing."
Renewing Switch Ties— (Acct. 220-b)	State number, length, kind of ballast, condition of cribs, singly or in sets and on main or side track....................	Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, tamping, refilling cribs, dressing ballast, carrying and piling old tie for burning, if less than 50 feet. If new tie is moved more than 100 feet or old tie moved more than 50 feet, separate time consumed loading, unloading and trucking. If ballast is cleaned, the time consumed should be reported separately.
Replacing Frog— (Acct. 220-d)	State weight of rail, frog number and location. Show time trucking, distance trucked and number of flagmen used...........	Removing old frog and plates, placing new frog and plates, full spiking, and flagging. Separate time consumed loading, unloading and trucking.
Replacing Switch— (Acct. 220-d)	State weight of rail, length of points and location. Show time trucking, distance trucked, whether on hand or push car, and number of flagmen used.....................	Removing old switch, placing and bolting new switch, adjusting and flagging. Separate time consumed loading, unloading and trucking.
Replacing Guard Rails— (Acct. 220-d)	State weight of rail, length of guard rail, number of clamps, whether plated or unplated, and location. Show time trucking, distance trucked, whether on hand or push car, and number of flagmen used.	Removing clamps, removing old guard rail, placing new guard rail, replacing clamps and flagging. Separate time consumed loading, unloading and trucking.
Replacing or Installing Guard Rail Clamps— (Acct. 220-d)	State whether replacing or installing, number of clamps and make. Show time trucking, distance trucked, whether on hand or push car, and number of flagmen used...............	Removing old clamps and placing new. If a large number of clamps are being replaced or installed, separate time consumed loading, unloading and trucking.
Applying Tie Plates— (Acct. 220-d)	State number of plates applied. Show number of plates, distance trucked, whether on hand or push car, and number of flagmen used...............	Pulling spikes, adzing, placing plates and spiking to gage. Separate time consumed loading, unloading and trucking.
Applying Anti-Creepers— (Acct. 220-d)	State number and kind. Show number of anti-creepers, distance trucked, whether on hand or push car, and number of flagmen used...............	Moving ballast, applying anti-creeper and tightening. Separate time consumed loading, unloading and trucking.

Exhibit D

Single Operations—Concluded

Kind of Work.	Manner of Reporting.	Items To Be Included.
Replacing Other Track Material not Specified Above— (Acct. 220-d)	State amount and kind. If trucking is done, show amount of material, distance trucked, whether on hand or push car, and number of flagmen used...	All operations required to remove old material and install new. Separate time consumed loading, unloading and trucking.
Cleaning Switches— (Acct. 202-b)	State number cleaned...........	Include time cleaning frog, switch and derail.
Cleaning Snow and Ice— (Acct. 272)	State number of switches cleaned. Make separate report of cleaning platforms...........	Include time cleaning frog, switch and derail.
Cleaning Weeds— (Acct. 202-b)	State number of feet cleaned and kind of ballast, and give location.........................	Removing weeds from ballast and scuffing shoulder.
Cleaning Right of Way— (Acct. 202-b)	State amount cleaned by feet of track and give location.......	Removing miscellaneous scrap, drift, dirt and other material from tracks and right of way.
Mowing— (Acct. 202-b)	State amount mowed by feet of track, number and width of swathes and give location......	Cutting and disposing of brush, grass, weeds, etc.
Ditching— (Acct. 202-a)	State location, amount in feet and method. If wheelbarrow is used, state number of loads and distance wheeled. If ditching car is used, give same information..........................	Constructing or cleaning tile or open ditches. Include time placing and removing plank for trucking, laying and removing track for ditching cars, loading, trucking and unloading dirt. If steam ditcher is used special report to be made.
Patrolling— (Acct. 202-c)	State distance covered in miles..	When track walker is tightening bolts or doing other work while patrolling make separate charge.
Trucking— (Acct. 220)	State amount and kind of material, distance trucked, whether on hand or push car, and number of flagmen used.......	Loading, unloading, trucking and flagging. (Any material handled on hand, push or motor cars.)
Loading and Unloading— (Miscellaneous Material) (Acct. 220)	State amount and kind of material and kind of car, whether box, flat, gondola or hopper moving or standing...........	Unloading, carrying and piling material or carrying and loading material.
Wasting Slag and Refuse— (Acct. 202-g)	State kind of car, number of cars unloaded and location.........	Unloading and spreading slag and refuse. If tracks are thrown or raised in connection with unloading make separate distribution of time.
Cleaning Ballast— (Screens or Forks) (Acct. 202-b)	State number of cribs and depth; feet of shoulder width and depth; and feet of center ditch, giving depth and track centers.	Removing ballast from shoulder, cribs and center ditch, cleaning with forks or screens, replacing cleaned stone, dressing ballast and disposing of refuse.

Exhibit D

COMBINED OPERATIONS

Kind of Work.	Manner of Reporting.	Items To Be Included.
Ballasting— (Preparing roadbed and applying ballast, Acct. 220-a. Applying ties, Acct. 220-b)	Distribute time to the following items: Feet of track stripped, feet of roadbed prepared, number of ties renewed, number of ties respaced, feet of track ballasted, number of cars of ballast unloaded, feet of first raise, feet of second raise, feet lined, feet of track dressed and amount trucked. For details of reporting each separate item, see instruction for reporting that particular item..........	Stripping track: Digging out and disposing of old ballast from cribs, center ditch and shoulders. (If old ballast is used to build standard roadbed section, charge second handling to Preparing Roadbed.) Preparing Roadbed: Widening and preparing subgrade to receive ballast. Renewing Ties: Carrying new tie if less than 100 feet, removing old tie, carrying 50 feet and piling for burning, placing new tie, placing plates, spiking to gage, temporary surface and flagging. Respacing: Cracking up spikes, driving ties to place and driving down spikes. Unloading Ballast: Releasing ballast cars. First Raise: Jacking up track 4" to 6" tamping and flagging. Second Raise: Jacking up track 4" to 6" tamping to final surface and flagging. Lining: Throwing to standard centers and detail lining. Dressing: Dressing center ditch and shoulders to standard section.
Surface and Raise Out of Face and Renew Ties— (Applying ties, Acct. 220-b. Surfacing track, Acct. 220-e)	State number of ties renewed, number of ties respaced, feet of track surfaced, feet of track lined and feet of track dressed. If ties are trucked state number and distance trucked...... If runoff at end of day's work is tamped as solidly as other track raised, one half of it may be included in "Feet of Track Surfaced." For details of reporting each separate item, see instructions for reporting that particular item...............	Renewing ties: Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, carrying and piling old tie for burning, if less than 50 feet. Respacing: Driving tie to place. Surfacing: Cribbing, jacking up track, tamping and flagging. Lining: Breaking down shoulder, lining track, replacing and dressing ballast. Dressing Ballast: Unloading ballast to refill cribs, dressing cribs, shoulder and centre ditch.

Separate distribution of time must be made for any items of work not covered by the above list.

Time charges for one item must not run over into the charge for another item. For instance, in surfacing, if there is any lining or gaging, a careful separation must be made to each class of work and not lumped as surfacing.

The time consumed loading, unloading and trucking material is in all cases included in the cost of applying the material, but a separate distribution of the time consumed on this work must be made.

The time flagging must in all cases be charged to the work being protected.

Exhibit D

REPORTING "OTHER DEPARTMENT" WORK

In order that the time spent on work for other departments may be properly separated from the time spent on the various items of maintenance work the following list of charges to "Conducting Transportation" and "Motive Power" is given as a guide:

Conducting Transportation

Cleaning stations.
Cleaning towers.
Cleaning cinders from tracks at designated points.
Cleaning refuse from cars.
Handling coal at tipples.
Handling coal at water stations.
Handling coal at stations and towers.
Handling coal for engines.
Lighting switches and station lamps.
Throwing switches.
Renewing batteries—Interlockers.
Renewing batteries—Semi-automatic signals.
Renewing batteries—Automatic signals.
Feeding and watering stock.
Burying stock.
Pumping water.
Hauling water.
Handling engine sand.
Wrecking.
Transferring freight.
Handling baggage.
Handling U. S. mail.
Assisting hostler.
Handling stoves, furniture and station supplies.
Handling ice.
Watching crossings.
Repairs to outside property account accidents.
Recharging fire extinguishers.
Draw bridge operation.
Floating equipment operation.
Unloading slag—wasting.

Motive Power

Repairs to freight cars.
Repairs to passenger cars.
Repairs to floating equipment.
Repairs to work equipment.

The items of work listed above must be scheduled by the Supervisor when possible and when so scheduled will be posted on Daily Record Sheet (Exhibit G) under Supervisor's Schedules and the detail shown on a supplementary statement accompanying the monthly report. Likewise items of "Ungraded Work" will be posted as provided for in instructions.

Any items of work contained in the above list which are not scheduled by the Supervisor and which are not classed as "Ungraded Work" will be posted on Daily Record Sheet (Exhibit G) under "Unscheduled Other Departments" and graded at 67 per cent.

Exhibit F

WORK ORDER

Section No.................. OUTLINE OF WORK	Location of Work			Time to be Consumed
	Track	From	To	

Order No....................

....19......

.... **Supervisor**

	Hour	Date
Work Started	....	....................19......
Work Finished	....	....................19......

....**Foreman**

Miscellaneous work which is not covered by a standard schedule will be scheduled by the supervisor as follows:

The supervisor from his experience will estimate conservatively the time which would be required to do the work under ordinary conditions. This estimate will represent an average performance of 67 per cent efficiency from which the standard hours representing 100 per cent efficiency will be computed by taking 67 per cent of the supervisor's estimate and shown on the dispatch.

On the Monthly Record of Track Work Efficiency (Exhibit H), there is a column headed "Total Payroll Hours," the total of which must check with the totals shown on the payrolls. This is not possible if any time is omitted; therefore, all work of whatever nature performed by track men must be recorded. All work not scheduled will be posted in a column headed "Ungraded Work," entering the actual hours only; no standard hours or percentage will be shown.

[7]METHODS OF PROGRAMMING MAINTENANCE OF WAY WORK, LOOKING TO THE MOST ECONOMICAL APPLICATION OF LABOR

The orderly prosecution of maintenance of way work throughout the year is essential to its most economical conduct. It is promoted by:

(1) The preparation of a budget of the work to be done during the year and the authorization of this budget for the year, if possible, or quarterly at least, sufficiently in advance of the inauguration of the work to enable materials and men to be collected in an orderly manner.

(2) The equalization of expenditures on roads where it is practical in accordance with the plan authorized by the Interstate Commerce Commission to eliminate the wide fluctuations in expenditures from month to month.

(3) The preparation of a detailed program in which the work authorized is scheduled so that it may be done at the most economical season consistent with the most efficient utilization of forces.

(4) The carrying of this program down to the local divisions and to the individual gangs on those divisions in order to enable the work of these men to be directed to the best advantage.

[8]ECONOMY IN USE OF LABOR-SAVING DEVICES

(1) The economy derived through the use of the labor-saving devices such as motor cars, weed killers, rail cutting and building-up devices, tie tampers, rail layers, ditchers, and locomotive cranes has been demonstrated and their use recommended.

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[7] Adopted, Vol. 26, 1925, pp. 1008, 1427.
[8] Adopted, Vol. 27, 1926, pp. 1044, 1453.

[1]METHODS OF MAINTAINING MOTOR CARS

The varying conditions on different railroads do not permit the universal acceptance, in all details, of any specific outline of an organization for the maintenance of motor cars, especially on those railroads which use only a limited number of cars. However, certain fundamental principles can be recommended for the establishment of an organized system which will obtain reliable service at an economical cost. The following principles, while essential to roads having a large number of motor cars, also apply in some degree to all railroads, depending upon the number of motor cars in service.

(1) The instructions for motor car operators should be plain and sufficient, and should be rigidly enforced. Rules relating to the care and operation of motor cars, included in the "Rules for the Guidance of Employees of Maintenance of Way Department" in the Manual, will serve as a guide in formulating these instructions.

(2) Motor cars must be kept clean, and must be inspected regularly by the operators. Clean cars give longer service, with less trouble, and cost less for maintenance. Clean cars indicate that inspections are being made regularly by the operator. This will aid in detecting defects before they become serious.

(3) Stores should be centrally located, for rapid distribution of repair parts, in order to get cars back into service with the least delay. Requisitions should be judiciously checked. The use of relief cars and relief power units will reduce delay in the event of motor car failure.

(4) The emphasizing of field repairs while on the job, and the sending of cars to shops for overhauling on a schedule regulated in accordance with the current output of the shop, and based upon the service and mileage that should be reasonably expected from the car, will insure maximum service from cars.

(5) Motor car shops centrally located and wholly under the control of the maintenance of way department, should be maintained for repairing worn or damaged cars. Modern equipment, especially designed to meet the requirements of motor car repairs, should be provided.

(6) The organization for the maintenance of motor cars should be headed by a practical railroad man, with sufficient executive ability and sound mechanical knowledge to supervise the maintenance and operation of motor cars over the entire system. To be most successful this System Supervisor should have authority to institute certain regulations for the care and operation of motor cars, and to enforce them. The success and value of motor cars depend just as much on the methods of maintenance and operation as upon the cars themselves. The System Supervisor's duties should embrace direct control of all mechanical details of the cars, supervision of all maintainers, responsibility for correct individual and system reports, regulation of purchase of cars and supplies in conjunction with the Stores Department, and supervision through other officers of the care and operation of motor cars.

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[1] Adopted, Vol. 27, 1926, pp. 1028, 1452.

(7) Uniform records of inspection, and of cost of maintenance and operation are indispensable in determining the most economical type and make of motor car. Such records will indicate whether an organization is operating efficiently, and will furnish a basis for comparison. These records will also indicate the expense justifiable in keeping a car in condition for service. In keeping these records the forms presented in Exhibits 1, 2, 3 and 4 are recommended.

(8) Motor car maintenance expense can be reduced through the adoption of the fewest number of makes and types of cars by each railroad to best meet its needs and requirements. The use of standard parts interchangeable with various makes of cars is recommended to reduce investment in stock parts and to lower maintenance costs.

Exhibit A

.... RAILROAD

MOTOR CAR CONDITION REPORT

....................Division Date....................

Class.......... No.......... Manufacturer.............. Service..............

Location.................. Date.............. Date Last Inspected..........

	Good	Fair	Bad	Remarks
Body				
Safety Rail				
Rail Sweep				
Wheels				
Axles and Bearings				
Brake				
Bolts and Fastenings				
Coupler				
Spark Coil				
Batteries				
Wiring				
Switches				
Timer				
Spark Plugs				
Magneto				
Tank and Connections				
Connecting Rod				
Piston and Rings				
Wrist Pin				
Cylinders				
Coaster Valves				
Exhaust Valves				
Intake Valves				
Carburetor				
Cam Shaft				
Main Bearings				
Transmission and Drive Gear				
Crank and Gear Case				
Lubrication				
Fuel Supply				
How Kept				
General Condition and Care				
Gage				
Any Unauthorized Appliances (yes or no)				
Proper Signal Equipment (yes or no)				
Time Card Carried (yes or no)				

This report to be made by Division Motor Car Inspector, covering all cars in his territory, regardless of position held by employee using car or department in which employed, and must be signed by employee using or in charge of car. Use (X) to indicate condition of parts; use back of sheet for further explanation.

This report shows true condition of car:

....
Division Motor Car Inspector

....
Foreman or Employee in Charge of Car.

Exhibit 2

.... RAILROAD

MOTOR CAR OPERATOR'S AND MAINTAINER'S MONTHLY REPORT

Car No

Month of 192 Type

Car Owner Manfr

District Location Sec No

Leave Blank

	Amount	Price	Cost
Days out of service account bad order			
" " " " idle, including Sundays and Holidays			
Number of miles operated during month			
Gallons clear gasoline used during month			
" mixed " " " "			
" clear kerosene " " "			
" mixed " " " "			
Quarts cylinder oil " " "			
Pounds cup grease " " "			
Number feet belt " " "			
" batteries " " "			
" spark plugs " " "			
" canvas covers " " "			

General condition of Car Good Fair Bad

(Underline the word which shows car condition)

Remarks

. ...

Motor Car Operator

Repairs Made During Month (Detailed)

Description Labor Performed and Repair Parts Used	Labor Cost		Material Cost	Total Cost Labor and Material
	Shop	Field		

. .. . 192

Motor Car Maintainer

Exhibit 4

....Railroad

ROADWAY MOTOR CAR SERVICE AND MAINTENANCE COST

Year Ended December 31, 192..

No. of Cars	Type	Total Car Days	In Service		Out of Service				Total Miles Run	Fuel, Lubricants and Other Supplies		Cost of Repairs					Cost Operation and Maintenance		
			Car Days	Percent of Total	Account of Awaiting Material and Repairs		Account Idle, Including Sundays and Holidays			Total Cost	Cost per Mile	Shop Labor	Field Labor	Material	Total	Average per Mile	Total	Per Mile	Per Day of Service
					Car Days	Per cent of Total	Car Days	Per cent of Total											

....Railroad Exhibit C

RECAPITULATION OF ROADWAY MOTOR CAR REPORTS

Division	Class of Service	Location
....	....	....
....	....	....
....	....	....

Car No........................ Engine No........................ Mfg'r Shop No........................ Mfg'r........................ Model........................

Month 192...	Total Car Days	In Service Car Days	Out of Service		Total Miles Run	Fuel and Lubricants		Cost of Repairs			Total Cost Labor and Material
			Awaiting Material and Repairs	Account Idle, Including Sundays and Holidays		Gasoline Used Gallons	Lubricating Oil Used Gallons	Shop Labor	Field Labor	Material	
Brought forward from previous report											
January											
February											
March											
April											
May											
June											
July											
August											
September											
October											
November											
December											
Total for Year											
Grand Total											

COMMITTEE XXIII

SHOPS AND LOCOMOTIVE TERMINALS

[1]ENGINE HOUSE DESIGN

Form

(a) The circular form under ordinary conditions is preferable.

(b) Special conditions may render a rectangular house desirable, such as restricted location, small number of engines handled, greater ease of providing "Y" than turntable, etc.

(c) At shops where a transfer table is used, a rectangular engine house served by the transfer table may be desirable.

Turntable

(a) The turntables should be long enough to balance the engine when the tender is empty.

(b) A deck turntable is preferable to a through table when the cost of construction is no greater.

(c) At important terminals, turntables are most economically operated by mechanical means.

Where electric power is available, an electric tractor is the most efficient means of operating a turntable. The power wires may be led to the table either underground or overhead.

Where electric power is not available, a compressed air motor may be used to propel the table. In this case, the locomotive itself usually furnishes the compressed air.

(d) The deck on the turntable should be wide enough to provide a walk on each side and be protected with hand rails.

Turntable Pit

(a) The turntable pit should be drained and paved.

(b) The circle wall should be of masonry, with proper supports and fastenings for rails on the coping. A timber coping is considered a proper support and preferable to a rigid masonry coping.

(c) The circle rail should preferably bear directly on masonry base.

(d) Easy access to the parts of a turntable for the oiling of bearings, painting and inspection should be provided in the design of the turntable pit, unless ample provision is made in the turntable itself.

Door Openings

The clear opening of entrance doors should not be less than 13 feet in width and 17 feet in height.

Doors

Doors should be easily operated, fit snugly, be easily repaired and maintained, and should admit of the use of small doors.

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[1] Adopted, Vol. 23, 1922, pp. 337, 1094.

Tracks

(a) Lead tracks to the turntable should line up with tracks of the engine house where possible.

(b) Tracks should be on a level grade and should be provided with stop blocks.

(c) Special fastenings of the track rails at the circle wall and on the turntable are desirable to prevent movement of the rails, to give good bearing and to lessen the damage from derailed wheels.

Position of Locomotive

In a circular house the locomotive should stand normally with the tender toward the turntable.

Length of House

The length of stall along center line of track should be at least 20 feet greater than the overall length of the locomotive to provide trucking space of 10 feet in width in front of the pilot and space in which to detach the tender and provide a walkway between it and the engine without opening the door.

Materials

(a) The materials used in construction of the house should be non-corrosive, unless proper care be taken to prevent corrosion.

(b) The additional security against interruption to traffic from fire warrants serious consideration of the use of a fireproof roof or dividing the engine house into units of approximately ten stalls by the use of division walls of fireproof material.

(c) The portion of the wall directly in line of the track where the engine is liable to run into it, should be so constructed as to be easily replaced or repaired when damaged.

Engine Pits

Engine pits should extend from a point 10 feet from the inner circle columns to a point 13 feet from the inner face of the outer circle wall. The clear width should be 4 feet; depth below base of rail, minimum 2 feet 6 inches, increasing with the slope of the floor of the pit to at least 3 feet. The walls should be about 2 feet 7 inches thick to provide proper support for jacking timbers. The clear width may be reduced a few inches when direct heating is used to permit the provision of recesses in the side walls for radiators and still allow ample support for the rails.

The floor should be convex and the drainage toward the turntable unless topographical conditions dictate otherwise.

Smoke Jacks

The smoke jacks should be fixed. The bottom opening should be not less than 42 inches wide, and long enough to receive the smoke from the stack at its limiting positions, due to the adjustment of the driving wheels to bring the side rods in proper position for repairs. The bottom of the jack should be as low as the engine will allow, and it should be furnished with a drip trough. The slope upward should be uniform to the flue. The area of the cross-section of the flue should be not less than 7 square feet. The jack should be preferably non-combustible. Wooden jacks properly built are considered reasonably non-combustible.

(This type of jack applies to all houses where regulations will permit. In some cities, where smoke abatement laws are in force, special types of jacks are necessary).

When the engine house is without a turntable, smoke jacks should be located at each end of each engine space.

Floors

The floors should be of permanent construction sloped so as to drain properly. The floor around the outer circle and for the outer bay or outer two bays where trucking is carried on and most of the work is done, may advantageously be constructed of wood block, or vitrified brick on a concrete base, while the remainder of the floor between pits may for the sake of economy be of concrete.

Drop Pits

The number and type of drop pits depends on the purpose for which the particular house is used and the class of power handled.

Ordinarily, a drop pit should be provided for driving wheels and supplemented as required by drop pits for engine truck, trailer, and tender wheels.

At points where considerable work is customarily performed on the wheels, the use of a drop table or unwheeling hoist should be considered.

Heating

(a) Heat should be concentrated at the pits.

(b) The general temperature of the house should be kept between 50 and 60 degrees Fahr.

(c) The recommended method for heating houses of ten stalls or over is by hot air driven by fans through permanent ducts located under the floors where practicable. The outlet should be located in the pits under the engine portion of the pits, and fitted with dampers to shut off the heat when necessary. Temperature of the hot air at the pits should be 130 to 150 degrees Fahr.

The fan and distributing system should have a capacity for changing the air from three to four times an hour. The fresh air should be taken from outside the building. The fan intake should be so designed as to permit the use of all fresh air, all inside air, or part fresh and part inside air. A certain amount of recirculation, depending entirely on conditions, is permissible, particularly when the doors stand open for any length of time.

(d) In a small house, or in a larger house in some climates, analysis may show the direct system of heating to be more desirable. In such a case, the vacuum return system should be used. Radiators should be placed in the pits and properly protected from falling parts, and also on the outer walls and end or fire walls. Radiators on the outer walls should be so located as to be clear of the path an engine would take in going through the outer wall.

Windows

(a) The disadvantages of skylights are so much greater than their advantages as to make them undesirable.

(b) Windows in the outer walls should be made as large as practicable with the largest glass or light area consistent with the strength of the structure. In general, the lower sill should be not more than 4 feet from the floor and the space between window frames and columns or pilasters and girders only that necessary to secure the window frames.

Windows in doors, when provided, should be furnished with wire glass.

Electric Lighting

General distribution of illumination should be provided either by:

(a) Individual lights between pits arranged to avoid shadows, 300 to 500 watts to a stall, or;

(b) Flood lights on the outer and inner circle walls so arranged as to diffuse rays, eliminate the glare common with flood lights and avoid deep shadows. Usually two 100-watt lamps on the outer wall and one 60-watt lamp on the inner wall are sufficient.

Either system should be supplemented by plug outlets for drop cord lamps in each alternate space between pits.

Piping

(a) The engine house should be provided with piping for air, steam and water supply and for boiler blowoff. The latter line should discharge outside the house and when a boiler washout system is installed, should discharge into the blowoff reservoir.

(b) A boiler washout and refilling system is ordinarily desirable to provide hot water for washing and refilling and to make use of the steam and water blown off from locomotive for this purpose.

(c) The steam outlet should be located near the front end of the boiler. The blowoff line, the air, washout and refilling water and cold water connections should be near the front end of the firebox. Connections should be provided in alternate spaces between stalls, except for the blowoff line to which connections should be provided between each stall.

(d) Steam and hot water piping should be insulated.

Machine and Tool Equipment

The space provided for machine tools and the extent of machine and tool equipment will depend entirely upon the location and method of operation of the house and must be made a subject of study for each house.

Mechanical Handling Devices

Consideration should be given in the design of an engine house to the use of traveling cranes, jib cranes or monorails and provision made in the design of the structure for future installation if such is considered probable.

[2]THE VENTILATION OF ENGINE HOUSES

General

The following are recommendations for general practice in the ventilation of engine houses. They do not apply to houses which are equipped with a mechanical system for smoke removal consisting of special jacks, ducts, fans and stack. Such a system is not recommended for general use in connection with ventilation.

Smoke Jacks

Smoke jacks should be of the fixed type, at least 42 inches wide, and of such length (preferably at least 12 feet) as to receive the smoke from stack at its limiting positions, due to the adjustment of the driving wheels to bring the side rods in proper position for repairs. The position of the jacks in the roof should be established with the above condition in view and the elevation of bottom of hood should be 16 feet 6 inches at ends and 15 feet 6 inches at sides above top of rail. The area of flue opening should be at least 7 square feet. An annular space two inches in width should be provided around the flue. A locomotive entering the house should be spotted with smoke stack under jack as rapidly as consistent with safe handling and should always be kept in such position while under fire.

Steam Blowoff

Provision of a proper system of piping for blowing off steam from boilers should be made in every engine house. Where possible the steam blown off should be used for heating purposes in connection with a boiler washing system, but in all cases discharge should be made outside the limits of the engine house. A ventilator of standard design and at least 18 inches in diameter should be placed in the roof on the center of each stall and as nearly as possible over the center of steam dome of locomotives handled. This ventilator should be provided with extension if necessary so as to place same above highest part of roof. If regular blowoff piping is temporarily out of service, arrangements should be made to blowoff through portable pipe into this ventilator and the blowing off of locomotives without such provision should be absolutely prohibited.

The features above mentioned will, as heretofore stated, reduce the necessity for other ventilation provisions, but, as with the best of care in operation some smoke and steam will escape, the following additional recommendations are considered essential.

Cross-Section of House

As modern engine houses have stalls generally 100 feet or more in depth, at least one break should be made in roof and if desirable complete monitor may be installed. Such breaks or monitors should be provided with pivoted sash or a combination of pivoted sash and fixed louvres, depending upon climate.

Framing

Roof framing should be such that the rafters directly supporting the sheathing or other roof surface are in radial lines and without pockets so as to permit the free passage of smoke to eaves. At the high eaves directly under roof sheathing, if climatic conditions will permit, a continuous opening of four to six inches should be provided to permit the escape of smoke and steam, particularly at breaks and in monitors.

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[2] Adopted, Vol. 27, 1926, pp. 308, 1313.

Windows

Large windows should be provided in the outer walls with a generous provision of ventilating sections. As near a continuous row of these ventilating sash as practicable should be provided along the top of windows.

Heating

The relation of the heating system to the ventilation of the engine house is of course apparent. The provision of a hot blast heating system with supply of air taken either from outside or inside of house as conditions may require and circulation by means of underground ducts with outlets in pits and along the outer wall just above floor level is recommended for general use. Such a system designed for frequent air changes will result in the rapid clearing of atmosphere in house even under unfavorable conditions. The use of this equipment during the summer months will materially lower the temperature in the house as well as clear the atmosphere in same.

[3]ASHPITS

Types of Pits

Ashpits and methods of ash disposal may be conveniently grouped in the following types:

(1) Ashes are discharged directly onto ordinary track construction and thence removed by hand.

(2) Ashes are discharged into small shallow pits with the rails supported either on non-combustible walls or metal ties.

(3) The depressed track pit, where engines discharge ashes onto a platform a few feet below the rails, from which the ashes are shoveled into cars on an adjacent depressed track.

(4) The deep water pit, where ashes are discharged into a pit eight to twenty feet deep, nearly full of water, from which the ashes are loaded into cars with clam shell buckets operated by various types of cranes.

(5) The shallow water pit where the ashes are discharged into long shallow pits constructed between the rails and nearly filled with water, from which the ashes are removed with clam shell buckets operated by overhead traveling cranes.

(6) Pits where ashes are discharged into hoppers or a series of buckets, and thence removed by a great variety of mechanical means.

Track Layouts

The following features of track layouts are favorable to rapid handling of engines over ashpits and should be provided wherever possible:

(1) Sufficient track standing capacity at the approach to the pit to accommodate all engines which may arrive in fleets in rush hours, and which cannot be immediately taken care of on the pit.

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[3] **Adopted, Vol. 24, 1923, pp. 66, 1117.**

(2) Crossovers and other track connections to open yard or running tracks so that preferred attention may be given to any engine regardless of its time of arrival, and so that ash cars may be switched with a minimum interference with the movement of engines over the pit.

(3) Except at minor terminals, two or more tracks over the pit.

(4) Sufficient track space beyond the pit to enable the pit to be cleared of engines regardless of all other terminal work, particularly operations at the turntable.

(5) Track connections between the pit and turntable to allow engines to proceed outbound without using the turntable.

Capacity of Pits

Capacity may be defined as the number of engines that can be moved over a pit in a given period of time, and is determined for any given pit by the number of engines that can be accommodated on a pit at one time, and the average length of time the engines stay on the pit. The length of time an engine stays on the pit varies over a wide range, depending on the number of men cleaning the fire, the size of engine, kind of coal in the engine, length of run of the engine and the character of the fire cleaning performed, weather conditions, and unavoidable delays in moving engines after fires have been cleaned. Unless accurate information is obtained as to local conditions, for estimating purposes 45 minutes may be used.

General Requirements

(1) A pit should be designed to meet the requirements of the rush hour, which should take into account abnormal conditions which may obtain due to engines arriving in fleets on account of delays on the road, unusual weather conditions, etc.

(2) The design should, so far as possible, take into account the destructive effect of hot ashes and sulphuric acid upon the parts of the structure exposed to contact with the ashes and water.

(3) All pits should be equipped with water pipes conveniently arranged for quenching fire and for attachments of hand hose for use of fire cleaners on each side of each engine.

(4) In cold climates a hot water supply under pressure is desirable to expedite the cleaning of frozen ashpans at the more important terminals.

(5) All pits should have proper drainage.

(6) All pits should be designed to provide as great a degree of safety as practicable.

(7) The work of removing ashes should be done mechanically, so far as possible, to reduce the force employed to a minimum or to make the work easy and attractive to labor.

(8) Spare parts of mechanical equipment should be kept on hand, and generally, no mechanical equipment should be used which cannot either be replaced or repaired quickly.

(9) Liberal storage space for ashes should be provided. At most terminals the switching of ash cars should not be necessary more than once a day. There is a decided advantage where ashes can be handled directly to a storage pile.

(10) The disposal of ashes should be so arranged as not to actually delay cleaning of locomotive fires and handling of engines over the pit.

References

For information and reports covering the various types of pits, their advantages, disadvantages and detailed requirements, see Proceedings A. R. E. A., Vol. 18, 1917, pages 816 to 819; Vol. 21, 1920, page 151; Vol. 22, 1921, pages 621 to 648; Vol. 23, 1922, pages 263 to 322.

[4]ENGINE TERMINAL LAYOUTS FOR STEAM LOCOMOTIVES

(1) In designing an engine terminal layout, a thorough study of the traffic and operating requirements of the terminal should be made jointly by the Engineering, Operating and Mechanical departments.

(2) A terminal should be designed not only for present requirements but also to permit future expansion.

(3) Sufficient and properly laid out trackage should be provided to permit the prompt receipt of all engines immediately upon arrival and in advance of each facility for standing locomotives which may have to wait their turn, and so arranged as to provide for the orderly and expeditious movement of engines between the terminal entrance and the house.

(4) The required facilities should be provided and placed in proper sequence.

(Detailed information covering the layout and requirements is given in the 1926 Proceedings.)

[5]GENERAL LAYOUT AND DESIGN OF PASSENGER CAR SHOPS

The following essential points should be given consideration in designing Passenger Car Repair Shops:

(1) Suitable provision to be made for future expansion of all facilities.

(2) Capacity should be determined on basis of number of cars to be shopped in a given time, balanced against traffic demands and effect of manufacturing operations.

(3) All buildings to be of substantial fireproof construction, amply lighted, both natural and artificial; comfortably heated and well ventilated.

(4) Tracks in Coach Shop should have minimum spacing of 24 feet center to center, except where columns are located between tracks, when 12 feet from face of column to center of track should be provided.

(5) Tracks in Paint Shop should have minimum spacing of 20 feet, unless local conditions make it desirable for these tracks to line up with Coach Shop.

(6) Minimum spacing in the Stripping and Trimming Shed should be 20 feet and in the Truck Shop 15 feet.

(7) Overhead clearance in Coach Shop should be not less than 22 feet to bottom chord of roof truss.

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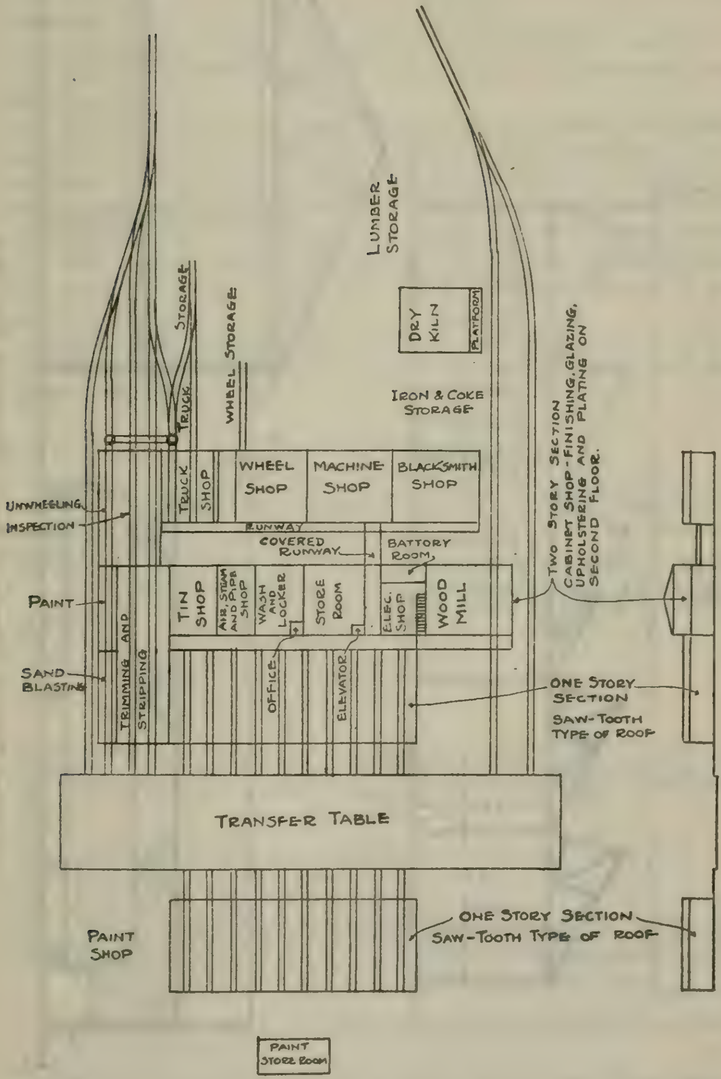
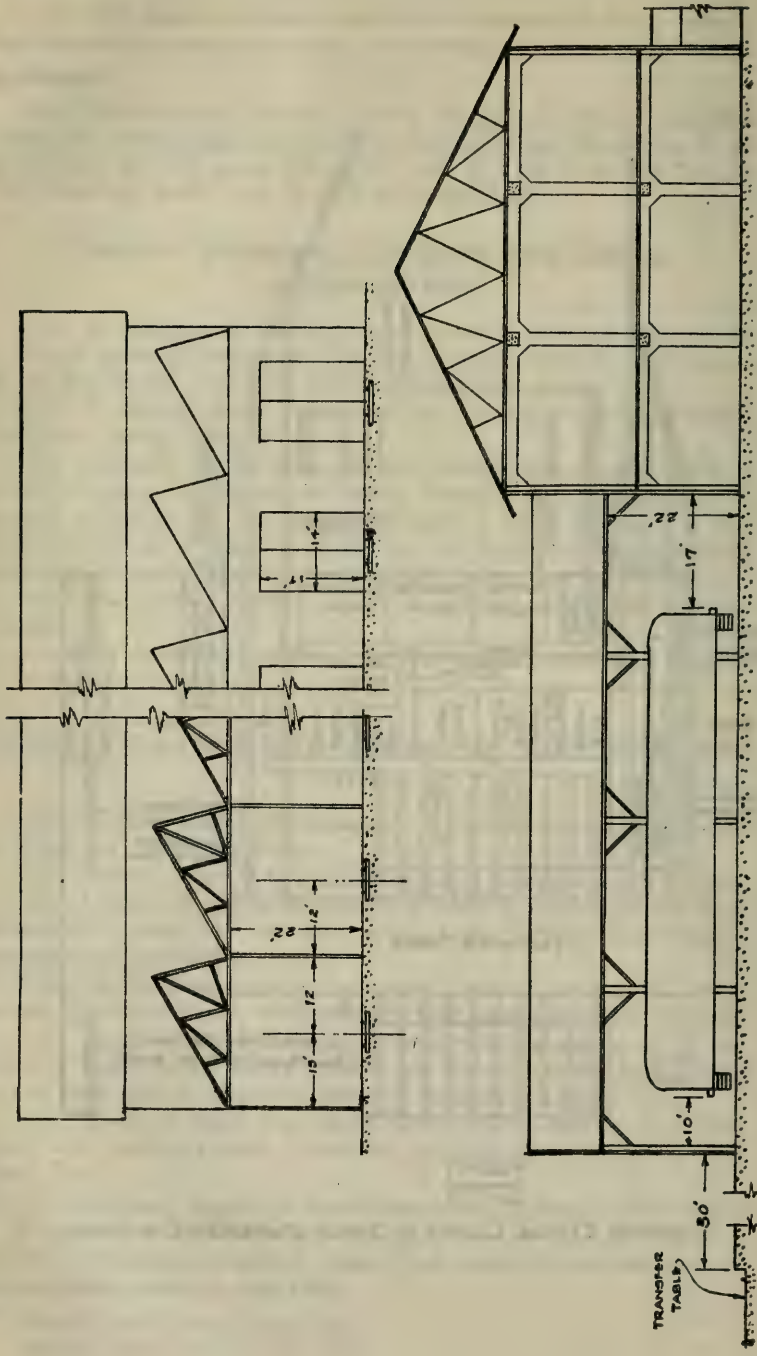
[4] Adopted, Vol. 27, 1926, pp. 293, 1312.

[5] Adopted, Vol. 22, 1926, pp. 303, 1312.



SUGGESTED TYPICAL LAYOUT OF SMALL PASSENGER CAR SHOP



Suggested Typical Layout of Small Passenger Car Shop

(8) Width of Coach Shop should not be less than the length of longest car plus 27 feet.

(9) Width of Paint Shop should not be less than the length of longest car plus 20 feet.

(10) Doors should provide a clear opening of 14 feet by 17 feet unless otherwise prescribed by law.

(11) Generous use of cranes, hoists and monorail is desirable.

(12) Layout to be such that all operations follow in logical sequence so far as possible.

(13) Manufacturing departments should be grouped as conveniently as possible to the point where the respective parts are applied.

(14) Main and sub-storehouses should be located as centrally as possible to the departments they serve. Sufficient sub-storerooms should be provided as to provide material reasonably close to the shop operations.

(15) Paved roadways and walks of ample width are highly desirable.

(16) Ample storage space for cars to be shopped, as well as finished cars, is essential.

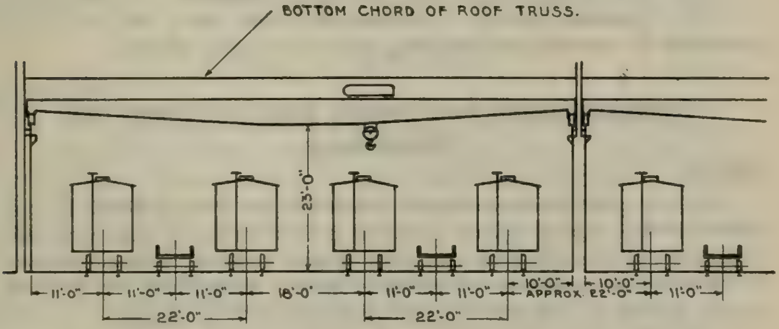
(17) Separate inspection facilities are desirable.

(18) Special provision should be made for preventing and fighting fires.

[6]FREIGHT CAR REPAIR SHOPS

(1) The distance from the center line of the outside car repair track in a car shop building to any projection on the outside wall should be not less than 11 feet.

(2) The distance center line to center line of repair tracks that have a standard gage material track between them should be not less than 22 feet.



Minimum Dimensions Recommended for a Freight Car Shop

(3) The distance center line to center line of repair tracks that do not have a material track between them should be not less than 18 feet.

(4) The distance center line to center line of car repair tracks where a row of columns is located between the tracks, should not be less than

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[6] Adopted, Vol. 26, 1925, pp. 137, 1261.

22 feet and in no case should the distance from face of columns to center line of adjacent repair track be less than 10 feet.

(5) The minimum distance from the top of rail to bottom of traveling crane bridge, in car shops that do not lift cars over each other, should be 23 feet.

(6) Car repair shops should be arranged so that cars can be switched from both ends.

(7) Material tracks in car repair shops and yards should be standard gage.

(8) That portion of the car repair shop floor between the outer rails of adjacent repair tracks, having a material track between them, should be paved or planked and suitable paved or planked roadways should be extended out into material yards to facilitate trucking and the use of tractors for handling material.

(9) In shops where cranes are not employed the overhead clearance, measuring from top of rail should be not less than 20 feet, door openings excepted.

(10) Except where otherwise prescribed by law, repair track door openings should not be less than 13 feet wide by 17 feet high.

(11) Suitable provision should be made in the formulation of plans to provide for reasonable extensions of all buildings and facilities.

(12) Suitable means should be provided for prompt and economical handling of materials and supplies through the application of cranes, hoists, monorails, supply tracks and roadways for tracks and trailers.

(13) It is recommended that fireproof or slow-burning construction be employed for the building structures.

(14) It is recommended that the roof and side wall construction be such as to afford maximum natural light and ventilation.

(15) Ample artificial illumination is recommended.

(16) Heat is recommended for the colder climates.

(17) Separate building is recommended with excess heat and good ventilation for painting and stenciling for cold or rainy climates.

[7]STOREHOUSES FOR SHOPS AND LOCOMOTIVE TERMINALS

General

(1) In practice very often the storehouse for these facilities is combined with the System, District or Division Storehouse, and even when this is not the case the storehouse may serve several shop and terminal facilities. In view of these conditions only the most general requirements can be given, as the size and location will be governed by the services required.

(2) The subject of storehouses is taken to include not only the storehouse proper but all auxiliary facilities consisting of sub-storehouses, oil storage, material platforms, paint stores, lumber storage yard and sheds, material racks, sheds for coal, coke, charcoal, firebrick, locomotive arch brick, storage for generating of oxygen and acetylene, scrap dock and reclamation sheds, etc. Sub-storehouses for shops and terminals are not necessary where the store delivery is in operation.

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[7] Adopted, Vol. 28, 1927, pp. 74, 1229.

Location

(3) The location of storehouses and their auxiliary facilities, switching tracks, etc., must be given due consideration by all departments concerned, giving full consideration to loading and unloading of cars, switching, delivery of material to users, the possibility of future expansion, the type and extent of roadway and equipment to be used in handling material.

Tracks and Roadways

(4) Track facilities should be provided for the receipt of incoming materials, for the loading out of material, for distribution to other points and shipment of scrap.

(5) Paved roadways should connect the storehouse with public highways and all parts of the shops and terminal served by the storehouse. These roadways should not only be provided to serve in the distribution of materials but should also provide easy access for fire apparatus, including sufficient space at hydrants for manipulating equipment.

These roadways should be 18 feet in width leading to all fire hydrants, should never be blocked and should have signs properly posted; in all cases quick access should be provided for the City Fire Department.

Construction

(6) Storehouses wherever possible should be one-story and all should be built of fireproof construction, except perhaps the small auxiliary buildings. Metal buildings may be used for the small auxiliary buildings where fireproofing is of importance, but the difficulty of heating this type must be considered.

Interior columns should be avoided in one-story buildings. In buildings of more than one story care should be taken that posts and racks are so spaced, to provide maximum storage, with least interference.

MAIN STOREHOUSE

Arrangement

(7) The primary consideration is the economical handling of material. The arrangement should be such as to insure ample natural light, the convenient handling, checking and inventorying of materials, and ease of supervision. In order to reduce cost of construction, storehouse floor and platform may be placed on practically the track or ground level with raised platform and ramp for unloading to and from cars. Racks should be so located that the handling of materials will be reduced to a minimum and so that there will be no dark pockets for the accumulation of rubbish, etc. Main aisles of ample width should be provided to allow for the handling of material by motor truck.

Arrangement of Racks

(8) The most general practice is to place the racks transverse to the house, thus permitting natural light from side windows to illuminate the aisles and racks. Some railroads place the racks longitudinal to the house to permit freer observation of the force, but such an arrangement requires more artificial lighting and more floor space.

In larger storehouses arrangement of racks, etc., should be such that electric tractors and trailers may be used in handling heavy material from one part of the store building to another.

The relative location of racks and windows may have a material bearing on the possibilities for fighting fires. Fire brigades frequently cannot enter a burning building but must direct hose stream through windows from outside.

Number of Stories

(9) A one-story house possesses advantages for easy and short trucking but where very large floor area is required a two or three story building is more suitable. The advisability of multiple stories would also be dependent upon the availability and value of ground space. Where more than one story is used the upper floors are used for offices (at one end), slow moving and light materials as for assembling place for work requiring the holding of material until it is assembled for a complete job.

Floor Loading

(10) Upper floors should be designed for a live load of not less than 250 lb. per square foot. The first floor, if built over a basement, should be designed for a minimum live load of not less than 300 lb. per square foot.

Elevators

(11) In multi-story buildings, elevators of at least four tons capacity should be provided. For large houses one elevator should be provided for each 20,000 square feet of floor area served. These elevators should be of sufficient size and capacity to handle an electric truck and trailer. The self-leveling type of automatic elevator with push button control is desirable. Floor openings act as flues to promote draught during a fire and should, therefore, be thoroughly enclosed. Entrance doors must be normally closed or be provided with fusible links to assure that they will close during a fire.

Ramps

(12) Instead of elevators, ramps inside of building to accommodate electric trucks have in some instances been found more efficient.

Chutes, Conveyors, Etc.

(13) Package chutes from upper floors to the lower floor are very convenient in the larger sized stores and should be located near the elevator. In some cases a dumb-waiter will answer the same purpose as the chute. Portable conveyor systems are very handy for handling and piling material that has only to be handled a short distance, and should be part of the equipment of the larger sized storehouses.

Lighting

(14) Electric lighting should be provided, with the lamps over the aisles and plug outlets at ends of the racks. The circuits should be arranged and controlled so that only the lights actually needed would be turned on.

Ventilation

(15) Ventilation should be given careful study, and the main storage part of storehouse, as well as the office portion, should be well ventilated so

that working conditions will be as near perfect as possible. Much of the material stored, especially electrical material, rubber goods, hose, packing, etc., should be kept where it is dry and the heat and ventilation should be arranged accordingly for it.

Heating

(16) Heating should be provided for the office portion and also for the stock and workroom sections, the latter at a less temperature than the former. Storerooms should be heated so that it is comfortable for the laborers to work in any part of it without wearing clothing that hampers them in their work. A temperature of 72 degrees for the office section and 60 degrees for the storeroom sections is recommended. If reducing valves are necessary on high pressure lines they should be of such type and so located as to be free from possibilities of tampering.

Office

(17) The office should be of sufficient size to accommodate the help, allowing a minimum of 64 square feet for each clerk, together with space for files and separate office for Storekeeper and in some cases for a General Foreman, and where desirable to consolidate forces, to also share office space with Master Mechanic, the medical organization and others. In one-story buildings the office should be at the end of the storehouse. Where there is a scarcity of floor space available in a one-story building it may be desirable to provide floor space on a second floor for offices, in which event the end wall of this second story section facing the roof of the one-story part should be constructed either without windows or if with windows these should be fire resisting. In buildings of two or more stories the office should be at the end of the second floor. If so placed, a fire wall should be erected to effectually serve as a cut-off between the two sections of the building.

Toilet Facilities

(18) Toilet facilities are usually regulated by governmental requirements but in any event adequate toilet and wash room facilities should be made for both office force and for storehouse laborers. Where women are employed rest room should also be provided.

Racks

(19) The open type of racks, of wood, steel or other fireproof material, with adjustable shelves, adapts itself better to the unit piling of material, and is recommended. Racks with one or two offsets are in common use, with base approximately 5 feet wide in case of one offset and approximately 6 feet wide in case of two, the upper section of case being usually about 3 feet wide, the offset affording a step to easily reach the upper shelf, which in all cases should be in plain view of a man standing on offset. Metal racks without offset will afford closer spacing and are more flexible, and as they reduce the amount of combustible material, materially reduce the fire hazard. They should be of such height that the upper shelf is in full view of a man standing on the floor. In no case should racks be contemplated which require the use of a ladder to reach the upper shelf.

Platforms

(20) Concrete platforms should be provided on track side along the entire length of storehouses and where motor trucks with trailer trucks are

used they should be equipped with rubber tires, and a 14-foot wide platform is recommended. All platforms should have ramps at the ends.

Fire Protection

(21) An adequate interior automatic sprinkler system is preferable; the next choice for inside the building being water pipe lines, with hydrants and hose reels. A sufficient number of fire hydrants with hose cart protection should also be installed outside the building. Regulation fire extinguishers should be distributed through the store buildings in accessible and plainly marked locations. Fire alarm boxes, where warranted, should be located at convenient points both within and without the stores. The location of all hydrants, hose reels, extinguishers, alarm boxes, etc., should be where they can be plainly seen in daytime, and well illuminated at night by electric lights.

YARD CRANES

(22) Casting platforms at large shops should have an overhead traveling crane the entire length of the casting platform. This crane should also cover the track or tracks serving the platform, so as to reduce to a minimum the handling of the castings from car to platform to a minimum. At small terminals locomotive crane or other self-propelled type may be used for this purpose.

CASTING STORAGE

Iron Racks, Pipe Racks, Etc.

(23) Local conditions will govern the location. They should, however, be located so as to reduce the handling from the car to storage and from storage to where they are used, to a minimum. Castings and other heavy bulky material should be stored on open platforms and at large shops under traveling crane. Where sheet iron is stored, all sheets larger than No. 10 may be stored outside except where climatic conditions prevent. These should be stored on edge in racks made of steel posts with the bottom ends embedded in concrete piers, unless they are to be handled by magnet and crane, then they should be stored flat.

If ground space permits tank and firebox steel should be stored adjacent to shop that will use the material. These racks will then be provided with overhead monorail that would economically handle the material into the shop.

Platforms should be designed for a live load of not less than 880 lb. per square foot.

OIL HOUSE

Location

(24) The oil house, with tracks and switching facilities, should be at one end of and separated from the storehouse and preferably located at a distance of not less than 50 feet. Oil storage should be in the basement and the fire floor used for delivery counter, pumps, oil drums, waste and similar material. Oil tank and piping in the basement should be painted white, to lighten up the basement and to readily show any leak that may occur.

For small stores where as elaborate facilities as described above are not necessary, oil may be stored in a basement under one end of the storehouse with counter, pumps, oil drums and waste on the first floor. The oil house portion should be separated from the storehouse by a fire wall.

Construction

(25) Oil houses should be built of fire resistive materials, including steel sash with wire glass and self-closing device on fusible link. Tanks of sufficient capacity should be provided in the basement except for gasoline and other high flash oils, which should be located outside with the tanks placed underground. Fuel oil storage tanks should be located outside and may be buried or placed above ground as local conditions warrant. Suitable provision should be provided in the building construction to provide for removal of any tank in the basement.

Pumps

(26) Self-measuring pumps are recommended for handling the oil that is stored in basement of oil house. These should be located on the first floor of the oil house. There are on the market a number of the enclosed pumps that are very economical and efficient. In no case should pitcher pumps or a pump that leaks oil around the pistons or delivery spout be used.

For the outside tanks and where volume of oils stored justifies for the oil stored in basement consideration should be given to the handling from tank to delivery counter by air. In such cases, small auxiliary reservoirs should be placed directly in front of the large tanks, the oil being fed into these small reservoirs by gravity through a check valve, thus preventing the application of air to the large tank.

Waste

(27) Sufficient space should be provided in the oil house for storage of waste, but preferably separated from the oil room by fire-resistive partitions in which openings are protected by automatic self-closing fire doors. Provision should be made so that broken packages of loose waste be kept in metal boxes with weighted covers held in open position with a fusible chain which will close cover in case of fire.

Where it is necessary to maintain mixing vats in oil house and the machinery for reclaiming grease, a separate room should be provided for this purpose; entrance from adjacent room should be protected by automatic fire doors. If of an extent, separate building should be provided.

Fire Protection

(28) An ample supply of foam extinguishers must be maintained for fire protection. Vapor-proof lamps controlled by an outside switch should be used. A barrage steam system should be installed with the added protection of sand in barrels and pails, the latter principally for small fires.

PAINT STORES

Location

(29) Wherever possible, this building should be part of the oil house, and where not possible, a fireproof building should be provided, located conveniently to paint shop. The shelving bins in the paint house should be of steel or other non-combustible material. Where the paint store is a part

of the oil house it should be separated from the oil storage portion with a fire wall in which are no openings.

LUMBER SHED

Location

(30) These should be located in the material yard with sufficient tracks so that switching and handling may be reduced to the minimum.

Construction

(31) These may be of frame construction and of sufficient size to keep protected all inside finished lumber. These sheds are usually built enclosed on three sides with one side partly open, this side being next to the track where the lumber is received in cars, and this open side should be sufficiently high so as not to interfere with the handling of the lumber between the car and the stacked lumber inside of the building.

In order to protect the lumber stored on the open side of shed, the roof is either given a wide projection or the top side skirted down to the line of the top of lumber piles. Lumber should be piled off of the ground and it is sometimes found a good practice to store lumber piles on secondhand rails supported by small concrete piers about 12 or 18 inches above the ground. The sides and rear of the shed are usually made of one inch boards with an inch space between them to allow for ventilation. This siding should not extend below the top of piers.

SCRAP YARD FACILITIES

(32) Ample space should be provided for handy unloading, sorting and classifying of scrap so as to obtain the greatest possible classification of the various grades and corresponding advantage of price in the sale thereof. Scrap yard and reclamation plant should be so located as to necessitate the minimum possible handling and trucking of material between these two units of a storehouse.

MISCELLANEOUS

(33) Torpedoes and fuses should be stored preferably in main building in a place segregated from regular storehouse material, with adequate provision for excluding moisture and for fireproofing the compartment.

(34) **Coal, Coke, Charcoal Bin or Sheds** should be located and so constructed as to permit of unloading direct from car and close to place where the material is to be used. At large storehouses these units of the facility should allow for unloading of these materials from cars to shed or bins by clam shell or crane.

(35) **Oxygen and Acetylene** should be stored in a separate building of light frame work construction, located not less than 50 feet from main building.

(36) **Fire Brick and Fire Clay Locomotive Arch Brick** should be stored in weather tight sheds as close to place where material is to be used as possible.

[a]TYPICAL LAYOUTS FOR STORAGE AND DISTRIBUTION OF FUEL OIL, INCLUDING FUEL OIL STATIONS BETWEEN TERMINALS

General

(1) Where oil is used as fuel for locomotives the facilities required include provision for unloading it from cars, for holding it in storage, and for delivering it to locomotive tenders.

(2) The details of design necessarily vary with the composition and gravity of the oil to be used and the climatic conditions to be encountered, as they affect the temperature which must be maintained in the oil for convenient handling.

Unloading Facilities

(3) Oil should be unloaded from tank cars by discharging direct into a trough or boxes of steel or concrete between the rails of track on which cars stand for unloading. Where boxes are used, they should be spaced at car-length intervals for convenience in spotting cars for unloading. Troughs or boxes should be equipped with metal covers, kept closed when not in use. The unloading facilities should be located on a track assigned for this purpose, preferably at some distance from buildings or other tracks, and so that it will be unnecessary for locomotives to pass over them. While tank cars are being unloaded, a sign warning against disturbing them should be posted between the first car and the switch.

(4) Unloading trough or boxes should deliver oil by gravity through pipe line to depressed sump from which it may be pumped to storage or delivery tank. Such pipe line should be of sufficient size and be laid with sufficient gradient so that oil will flow by gravity to the sump as fast as it will be discharged from the total number of cars which will be opened at any time. This should not be in excess of the capacity of the pumps.

(5) Sumps may be of steel or reinforced concrete and should be covered. They should have capacity of not less than one carload. If of steel, the pit should be drained or the sump should be anchored to prevent displacement by ground water when empty. The sump should be vented to draw off gases generated by heating oil in the sump tank, and in some circumstances it may be desirable to install an oil trap or barrier in the pipe line leading from the sump to the track trough or box to prevent the flow of gases from the sump to the track trough or box.

Storage

(6) The storage capacity which should be provided depends largely upon reliability and source of supply and probable variations in market price of oil. In general, there should be at each station sufficient storage to protect against any interruption which may occur in the delivery from the regular source of supply. Additional storage for the purpose of taking advantage of variations in market conditions may either be located at various terminals where oil is used, or concentrated at one conveniently located point.

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[a] Adopted, Vol. 26, 1925, pp. 152, 1263; Vol. 28, 1927, pp. 81, 1230.

(7) Cylindrical steel tanks of 55,000 and 80,000 barrels capacity, erected on leveled earth foundations, provide convenient and economical storage, and can commonly be secured promptly and at less cost on account of being standard construction with tank manufacturers. Roofs should be provided of steel or of wooden frame and sheathing, covered with asbestos, composition, tar and gravel, or sheet metal roofing. In permanent installations, or where oil having large gasoline content is to be handled, gas-tight steel roofs equipped with breather pipes with outlets outside the dike and floating roofs have the advantage of reducing evaporation of gases, and danger of fire. Each tank should be surrounded by an earth dike, enclosing below the elevation of top of dike a volume equal to one and one-half times the capacity of the tank. Where a special type of construction is used designed to minimize splashing and wave action, the capacity within the dike may be reduced.

(8) Adequate means should be provided for the escape of gases thrown off from the surface of the oil. The character and extent of such provision required will depend on the tightness of the roof and the character of the oil. It should be designed to reduce circulation of air over the surface of the oil to a minimum consistent with prevention of building up of pressure due to the accumulation of gases.

(9) Provision should be made for draining off water and refuse which may settle in the bottom of tanks.

Delivery

(10) Oil may be delivered to locomotive tenders by gravity from elevated steel tanks or under direct pump pressure. In general the former method is more convenient and economical. If the gravity system is used, particular attention should be given to the introduction and proper location of cutoff valves in the delivery lines, so that the flow of oil from the tanks can be immediately controlled.

(11) The size of delivery tank required varies with local conditions, as to receipt and handling of oil, but the capacity should, in general, be not less than the average amount of oil to be delivered in twenty-four hours.

(12) Valves should be provided for draining off water and refuse which may accumulate in the bottom of tanks.

(13) Delivery columns should be so constructed that spout can be swung to position and valve opened from the locomotive tender to be served. Spouts should have maximum freedom of movement in both horizontal and vertical directions, consistent with prevention of leakage. They should be provided with drip bucket, reversible end elbow, or other means to prevent drip.

(14) Means should be provided for measuring accurately deliveries of oil. Meters in delivery pipe lines or gages on engine tenders serve satisfactorily to that end.

(15) Some wastage of oil around an engine terminal is inevitable and provision which will reduce such wastage to a minimum is an important item in design of facilities for handling oil. If all unnecessary waste and leakage is eliminated the cost of recovery of waste oil is generally in excess of the value of the oil. In cases where such waste is excessive or becomes a nuisance, however, and causes damage to neighboring property, it becomes necessary to provide traps in drainage channels or sewers, equipped with

baffles, to catch the waste oil, separate it from water, and permit its recovery by dipping or pumping back to the sump. Such appliances are being used successfully.

Heating

(16) Where heavy oil is used or where cold temperatures are experienced, it is necessary to provide means for heating oil in cars, tanks and pipe lines, in order that it may flow freely. Such heat is best provided by steam pipes.

(17) Pipe coils in tank cars, which can be readily connected by flexible hose or pipe to steam pipe lines from the pump house, provide satisfactory means for heating before unloading. The discharge of live steam directly into the oil in the car may be resorted to in case heating coils are out of order or car is not equipped.

(18) Similar steam pipe coils provide satisfactory heat for storage and delivery tanks. In larger tanks they are more effective if enclosed with the end of the discharge line leading from the tank in a wood box so that the heat will be applied directly to the oil as it leaves the tank, and not disseminated through the whole tank full of oil. The heating of oil in pipe lines will often prove advantageous and may be accomplished by introduction of small steam pipe lines inside the oil lines, or by enclosing steam line inside an insulating box alongside the oil line. The latter method simplifies construction and maintenance, but requires more expensive first installation and greater consumption of steam in proportion to the results obtained.

(19) Where steam lines are installed in oil lines, it is necessary to take precaution against excessive heating. On this account, it is not recommended that steam lines be so installed larger than necessary for heating the pipe line. Steam for tank coils and other purposes may better be carried outside the oil lines.

Small Stations

(20) While the foregoing recommendations apply primarily to the larger stations, yet the general principles apply to the small stations except that their application requires special adaptation to the problem. In some cases, the oil is used direct from the cars; in other cases, storage from one or more cars is combined with delivery tanks, delivery being made either by gravity, pumps or air pressure.

[9]LOCOMOTIVE COALING STATIONS

Location

The location of coaling station should, of course, be selected with a view to serving the best interests from an operating standpoint. There are two general classes of locations for coaling stations, those at terminals and those at roadside locations between terminals. At terminals coaling stations should be located so as to serve both inbound and outbound tracks as recommended for engine terminal layout.

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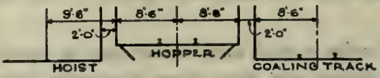
[9] Adopted, Vol. 29, 1928, pp. 376, 1308.

Track Layout

The mechanical coaling station can readily be arranged to deliver coal on one, two, three, four or even more tracks. Each location should be studied separately and the most suitable arrangement for that particular installation selected. A number of combinations which can be used, and which will provide suitable clearances and space for elevating equipment, are shown below.

①



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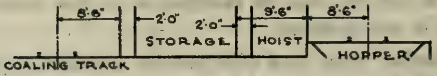

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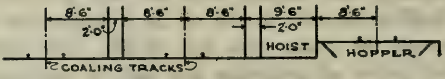

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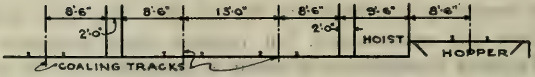

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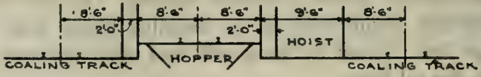

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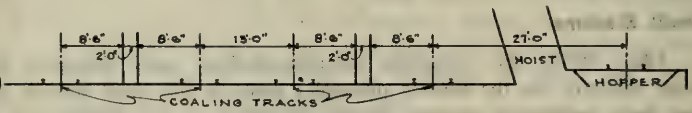

Hopper and Unloading Track

Except in cases where coal is delivered direct to locomotives without the use of a storage bin, the unloading hopper should be at least 20 feet in length and in larger installations it is desirable to use a greater length to secure additional storage before elevation and to avoid the necessity of accurate spotting of cars. In some very small plants where hopper bottom cars are used a less length of hopper may be justified to save construction cost. In some larger installations it may be desirable to use two unloading hoppers, in which case they should be on separate tracks. The unloading track or tracks should have a capacity both for loaded and for empty cars equivalent to the capacity of the storage bins. This will permit the operation with only one shifting of cars in each 24 hours and will thereby avoid any interruption to the unloading and elevation of coal.

Car Haul

It is usually desirable and convenient for use in spotting of cars over track hopper to have a mechanically operated car puller either as a separate unit or in conjunction with the hoisting equipment, and specifications should state definitely just what is required.

Storage Bins

The bins should have a total capacity at least equal to the consumption in 36 hours, and separate bins should be provided for different grades of coal where required. Except in cases of very small storage capacity it is good practice to divide the storage space into two bins even where different grades of coal are not handled. This will permit the cleaning or repair of a bin without affecting the operation of the coaling station seriously, and will also be desirable in the event of any future requirements for more than one grade of coal. Storage of coal in unused pockets should be prevented on account of fire hazards.

Hoisting Capacity

The hoisting capacity of the elevating machinery should be such as to permit the elevation of an entire 24 hours consumption during one 8 hour shift. In large and important stations it may be desirable to divide the hoisting capacity into two units to guard against breakdowns.

Power

Electricity for power purposes is yearly becoming available at an increasing number of locations. Where available its use should be adopted and the particular characteristics of the current to be used should be given. At locations where electricity cannot be secured, steam or internal combustion engines may be used and the particular one desired should be specified together with the requirements for the handling and storage of fuel.

Materials of Construction

Coaling stations may be constructed of wood, steel or concrete materials, but in any case the particular materials selected should be specified.

Crushers and Breaker Bars

Where coal in proper sizes cannot be obtained from mines, or when it is not economical to do so, provision should be made for the installation of crushers or breaker bars. Specifications should state type and capacity of crusher required, and whether it is desired to locate same in hopper or over bins. Location in hopper is generally preferred as this eliminates the necessity of carrying a heavy load with considerable vibration high up in the structure but it usually involves the use of an additional horizontal conveyor unit to avoid an abnormally deep pit.

Scales

Where accounting requirements are such that an accurate record must be kept of the amount of coal delivered to each locomotive, scales should be provided for that purpose. This can best be accomplished by the use of a small weigh hopper supported on scale levers over each delivery spout. Capacity of hopper should be slightly greater than the largest amount issued to a locomotive at one time.

Interior Chutes

Where conditions make it desirable to prevent, as far as possible, the breaking up of lump coal and the separation of lump and slack, provision should be made in the specifications for the installation of special chutes or other means of preventing long drops when discharged from conveyor into storage bins.

Housing

Vertical or inclined shaft for elevating equipment may be housed or not as desired. Specifications should definitely state whether or not housing is required, and if required the materials to be used should be fully described. It is usually the practice to provide a housing over unloading hopper if same is not so arranged as to be protected by the structure of the bins. Specifications should definitely state whether or not such a housing is required and if desired the materials to be used should be described.

Sanding Facilities

As it is usually desirable from an operating standpoint to supply locomotives with coal and sand at the same time, it is usual to provide with most coaling stations some character of sanding facilities. The importance of such facilities, no doubt, justifies their consideration in a separate and more detailed report but when combined with a coaling station project the specifications should provide for the requirement of unloading, storing and drying of green sand and for the elevating, storing and delivery of dry sand to locomotives.

Electrical Work

Electric wiring for light and power service is usually eliminated from coaling station contract work and handled by the railroad's own organization or on separate contract. Specifications should state definitely, however, as to this feature, so that contractors may understand whether or not electrical work should be included. In the event that same is to be included in the contract the specifications should describe in detail the extent and character of the work required.

TYPICAL SPECIFICATIONS FOR COALING STATIONS—MECHANICAL TYPE

General

1. These specifications are intended to cover the special features which will be required in connection with the design and construction of coaling stations. They shall be used with special specifications prepared for a particular installation, and also with the specifications of the American Railway Engineering Association for Buildings, Masonry, Iron and Steel Structures and Wooden Bridges and Trestles for items of structural design, character of materials and execution of work in so far as they apply.

Intent

2. It is the intention of these specifications to provide for the design and construction of a complete automatic coaling station of such type of con-

struction as may be specified, notwithstanding any omissions in these specifications.

Type of Construction

3. Storage bins and supports, hoist tower, and machinery house shall be constructed of timber, structural steel, or concrete, or a combination of same, as may be indicated in special specifications for particular installation. Foundations and hopper pit shall be of concrete construction, and in the event any all steel or concrete superstructure is specified no wood of any kind will be permitted in the finished structure.

Description of Plant

4. The plant shall consist of an unloading hopper or hoppers into which coal may be unloaded from cars and mechanically operated conveying equipment for elevating coal and bins for storing same and delivering to locomotives by gravity. The design of the plant shall be such that its operation is entirely automatic and that once the elevation of coal is commenced the operation shall be continuous without further attention on the part of operator to the elevating equipment until it is desired to stop the operation.

Design

5. Unit stresses used in design shall be in accordance with American Railway Engineering Association requirements as previously specified. As a basis for proposal unless otherwise specified an allowable soil bearing pressure of 3,000 pounds per square foot shall be used. All foundations shall be carried at least four feet below base of rail of adjacent tracks. Wind load shall be assumed at 30 pounds per square foot acting horizontally in any direction.

Track Arrangement

6. The required arrangement of hopper track and coaling tracks for which the plant must be designed is shown on location plan accompanying these specifications.

Storage Bins

7. Storage bins of the number and capacity required by the special specifications shall be provided and the capacity specified must be obtained without any trimming or handling of coal in bins. The sloping surfaces of bins shall be at least 45 degrees and all valleys and ridges shall be rounded to a radius of at least 18 inches.

8. In steel superstructures side plates of storage bins shall have a minimum thickness of ¼ inch and bottom plates ⅜ inch. In wood superstructures floor shall be lined with 3/16 inch steel plates, and side walls for full height of bin with No. 10 gage steel plates. Steel plate lining shall be securely fastened in place with countersunk flat head screws and shall be accurately fitted to slope of bin and gates and shall be properly curved at valleys and ridges.

Clearances

9. The design shall be such that when delivery chutes are raised all parts of the structure shall have clearances to tracks at least the equivalent of those adopted by the Association in the General Specifications for Steel

Railway Bridges, unless otherwise prescribed in special specifications or required by any law.

Unloading Hopper

10. The unloading hopper shall be of concrete construction 16 feet wide and at least 20 feet long in clear. The slopes shall be at least 10 inches vertical in 12 inches horizontal and all valleys shall be rounded to a radius of at least 18 inches. The lines of intersection of the side walls of the pit with the sloping floor of same shall be such that there will be at least 18 inches clearance below bottom of any track beam or breaker bars to the surface of the hopper. The unloading track shall be carried over the hopper on a structural steel beam under each rail, preferably spanning the entire length of the hopper. If an intermediate support is necessary a steel cross girder rather than a masonry pier shall be used. Rail will be installed by the Railway Company. The level of the unloading track at the unloading hopper shall, unless otherwise specified, be at least two feet above that of the coaling tracks. The Contractor shall waterproof the hopper and the hoist pit and shall guarantee this waterproofing for a period of at least one year after the acceptance of the plant.

Collision Walls

11. Frame work supporting storage bins, where adjacent to coaling tracks, shall be protected by means of a concrete collision wall extending the full length of the structure and to a point 4 feet beyond center line of supporting column at each end, at least 2 feet thick and extending to a height of 6 feet above the top of rail of coaling tracks. Openings shall be provided in these collision walls as required to permit the convenient salvaging of coal wasted off of tenders. These walls must have clearances as hereinbefore specified.

Screening and Separation

12. Each coaling station shall be provided with bar screen over bins, bars to be spaced about two inches apart to permit the separation of lumps and screenings in run-of-mine coal and shall further be provided with chutes and gates which will permit the delivery of any grade of coal to any bin. Operating mechanism for the control of these gates, screens, etc., shall be placed in convenient location at track level.

Ladders, Stairways, etc.

13. The Contractor shall provide ladders on the outside of the structure with the necessary platforms and railings to enable the operator to reach each gate, outside sheave, sand spout and sand pipe turn for repairing, oiling, or any other purpose. He shall also provide ladders on the inside of the bins so that the operator may be able to reach the bottom of each bin at each gate. He shall also provide a suitable stairway located where most convenient and extending from the track level to the top of hoist tower. All stairways, platforms and landings, either inside or outside of structure shall be provided with suitable railings and approved open grating treads. Open grating walkways 2 feet wide shall be provided on each side of unloading hopper, of an approved type.

Windows and Doors

14. The Contractor shall install necessary doors to provide access to structure and such pivoted steel windows as are necessary to afford ample light in all parts of the plant for the purpose of general inspection and safe performance of operator's duties.

For concrete and steel superstructure all windows and doors shall be of metal construction and glazed with wire glass.

Coaling Fixtures

15. The Contractor shall install, for the delivery of coal from each storage bin to each coaling track, a steel chute and gate of approved design. Each chute shall be equipped with an apron and baffle plate arranged so that fall of coal after leaving chute will be vertical and over center line of coaling track.

16. Chutes and gates shall be counterweighted and designed and installed in such a way as to permit of same being operated by one man when standing on top of locomotive tender or on overhead platform if provided. Counterweights shall be so adjusted that gate and chute will close and return to normal position when released by the operator. All outside parts of mechanism shall be hooded or otherwise protected against freezing. Hand hole shall be provided in side of chute between each gate and bin wall. Chutes when in low position shall be not less than 15 feet 6 inches above top of rail.

Power

17. The power to be used for operation of equipment shall be as provided in special specifications. In the event electric power is used the electrical equipment furnished shall conform to the characteristics of current available.

Hoisting Equipment

18. The hoisting equipment, which shall be furnished and installed by the Contractor, shall be entirely capable of hoisting the quantity of coal per hour as required by special specifications, without undue crowding, overloading or forcing. The hoist and power units shall be placed upon suitable concrete foundations and shall be placed at such an elevation as to allow ample clearance for gears, fly wheels and belting. All gearing and exposed parts and belting shall be protected in an approved manner by means of neat and substantial guards or railings so that operator will not be exposed to any danger from moving machinery. All machinery and other equipment shall be assembled and installed in a thorough and workmanlike manner. The transmission equipment and cables between hoist and hoisting tower shall be securely housed to provide adequate protection from weather.

Electrical Equipment

19. Electrical equipment and wiring shall be designed to operate with current of the kind and voltage as stated in special specifications. Electric service will be brought to the machinery house and connected to a main service switch by the Railway. Wiring for lighting will also be done by the Railway unless otherwise specified. Installation of motor, control and

all other necessary wiring and accessories to make a complete and satisfactory installation shall be furnished and installed by the Contractor. The rigid conduit system of wiring construction shall be used. Conduit shall be either sherardized or galvanized. Thirty per cent rubber compound insulated wire of approved brands shall be used for all wire having rubber insulation. All work must conform to the requirements of the National Board of Fire Underwriters, local municipal building codes and any special regulations of the lighting service company that may be in effect. Motors shall have proper speed and torque characteristics for the service for which they will be used. They shall have anti-friction bearings and insulation suitably impregnated to withstand moisture, coal dust, etc. If motor is located where it is subjected to excessive coal dust conditions, it shall be of the enclosed type. Control shall be of the magnetic type with all necessary accessories for proper operation of the equipment, equipped with under-voltage protection, overload protection of the temperature overload relay type, necessary push button stations, limit switches, etc. Control shall be of the type that will limit starting currents to values permitted by the local central station company supplying the electric service. Make and type of motors, control, and accessories to be used shall be approved by the Railway Company.

Plans to Accompany Proposal

20. Each bidder shall accompany his proposal with plans and descriptions in sufficient detail to indicate just what arrangement is intended to be furnished and proposal may also be accompanied by photographs of similar structure.

Plans to be Furnished by the Contractor

21. Immediately upon being awarded the contract, the successful Contractor shall prepare complete detail drawings of all parts of the structure and equipment, including machinery, buckets, gates, stairs, ladders, piping and wiring diagrams, if necessary. These plans shall be submitted in triplicate to the Engineer for approval, and upon completion of the work, the Contractor shall furnish a complete set of original or reproduced tracings on cloth of all drawings, which shall be a true record of the structure and equipment as built and installed. He shall also furnish, in triplicate, a complete list of all parts of machinery with pattern numbers or other designation to permit the ready ordering of repair parts. One of these lists shall be framed and glazed and hung in prominent location in machinery house.

Guarantee

22. The Contractor will be held solely responsible for the design of the coaling station and equipment in accordance with these specifications, and the checking and approval of plans by the Engineer will not relieve him of this responsibility. The Contractor shall guarantee the perfect operation of the entire plant and equipment for a period of one year after the completion and acceptance and shall agree to make good at his own expense any defects which may develop within that time, due to faulty design, workmanship or materials, and not caused by carelessness or improper

handling on the part of the Railway. The Contractor shall furnish a competent mechanic to instruct the Railway's operator for at least one week after the plant is placed in operation.

[10]LOCOMOTIVE SANDING FACILITIES

The basic requirements for sanding facilities are as follows:

(a) Capacity of green sand storage.
(b) Location of green sand storage.
(c) Method of handling green sand.
(d) Location, type and capacity of driers.
(e) Capacity of dry sand storage.
(f) Location of dry sand storage.
(g) Method of handling dry sand.
(h) Location for delivery of dry sand to locomotives.

NOTE.—Where term green sand is used it applies to wet sand.

Sand facilities may be separated into various types and combinations, the most frequently used being as follows:

(1) Ground storage plant either independent or in conjunction with coaling station.
(2) In combination with coaling station a partial gravity plant.
(3) In combination with coaling station a complete gravity plant.
(4) Complete mechanical sand plant either independent of a coaling station or in combination therewith.

Type 1

Plants of this type where ground storage of green sand is the distinguishing feature are becoming less popular with the general use of mechanical coaling stations of concrete construction. The extent of capacity for green sand storage is generally small, although in a few instances large installations of this type have recently been constructed at important terminals. Before deciding to use ground storage, however, even where the quantity to be stored is small, careful consideration should be given to the economy of operation as compared with overhead storage, taking into account the cost of handling from cars to storage and from storage to driers, as well as the cost of construction. Usually sand is unloaded from cars by hand shoveling or by locomotive crane and bin is a long narrow structure parallel to the unloading track. Sand is handled to driers by wheelbarrow and then shoveled into hopper or drier. Compressed air is generally used for the elevation of dry sand to storage compartment either in adjacent coaling station or independent of same. A diagram of the general arrangement above described is shown in Fig. 1.

A modification of this arrangement is possible where steam drier is used by placing drier and sand drum in pit below drier house floor and thereby securing a partial gravity installation. This arrangement is shown in Fig. 2.

In some cases elevated track can be used to advantage and sand unloaded from hopper bottom cars without shoveling or use of crane. A typical arrangement of this character is shown in Fig. 3.

An example of a relatively large installation of the ground storage type as recently constructed at an important terminal is shown in Fig. 4.

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[10] Adopted, Vol. 30, 1929, pp. 346, 1377.

Type 2

In plants of this type advantage is taken of the fact that in constructing a coaling station the provision of an additional overhead bin for green sand storage can be made without greatly increasing the cost of the whole structure. Where skip hoists are used sand can be unloaded in the same hopper and elevated by the same equipment as that used for handling coal. This arrangement has the disadvantage of interrupting the unloading of coal while sand is being handled and requires the cleaning of the unloading hopper, both before and after the operation, but if the quantity of sand handled is not excessive and the periods are not too frequent (not to exceed once a week) these disadvantages are more than offset by the elimination of investment in separate facilities. The green sand bin can be arranged to deliver sand by gravity to driers and from driers to sand drum. Elevation to dry sand storage bin also in coaling station is accomplished by compressed air. A typical example of the arrangement above described is shown in Fig. 5.

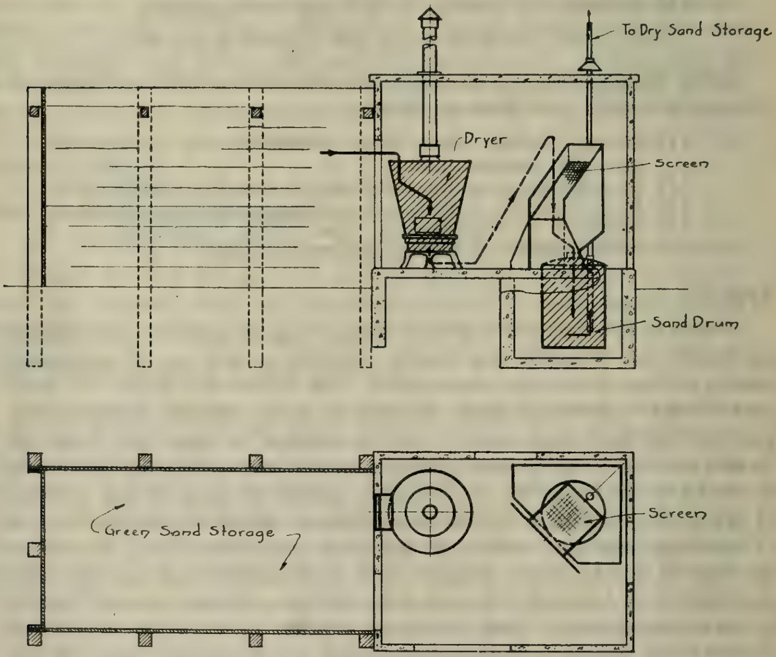

Fig. 1

Type 3

This type is very similar to Type 2 with the exception that a complete gravity handling is provided from green sand storage to delivery spouts to locomotives. This arrangement is possible where a small green sand storage

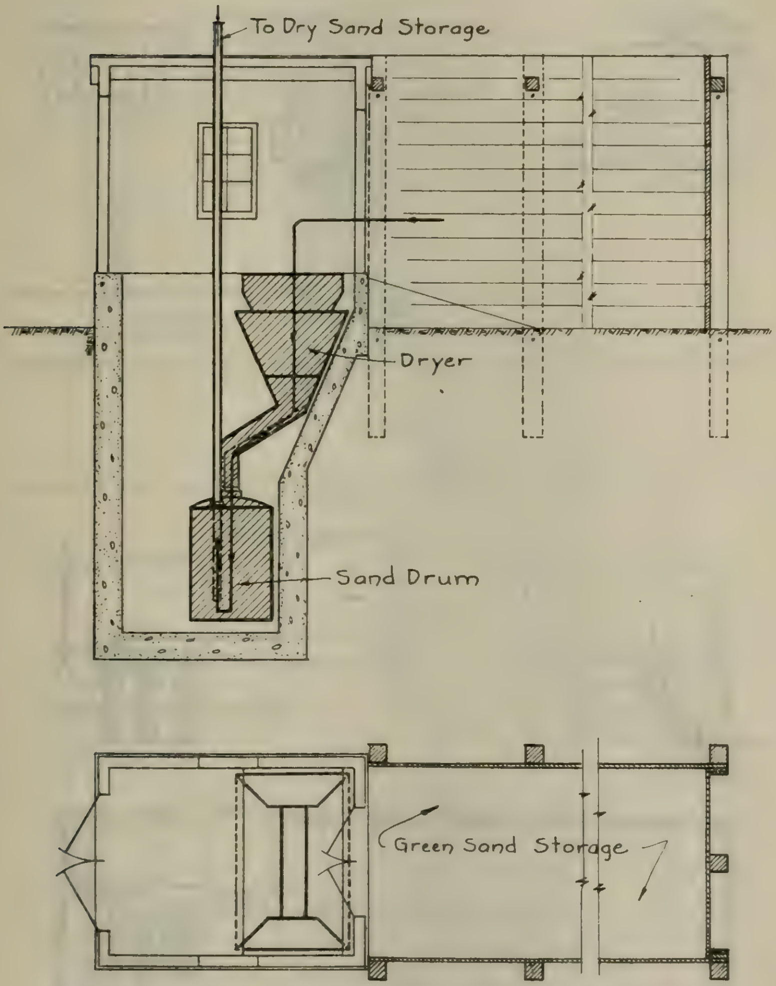

FIG. 2

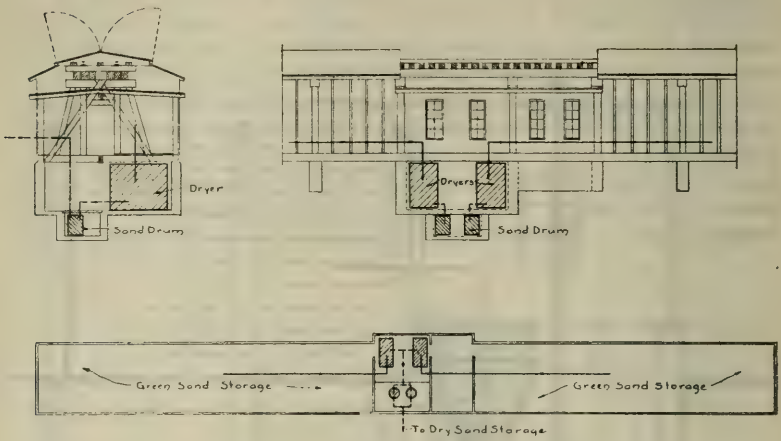
Dryer
Sand Drum
Dryers
Sand Drum
Green Sand Storage
Green Sand Storage
To Dry Sand Storage

FIG. 3

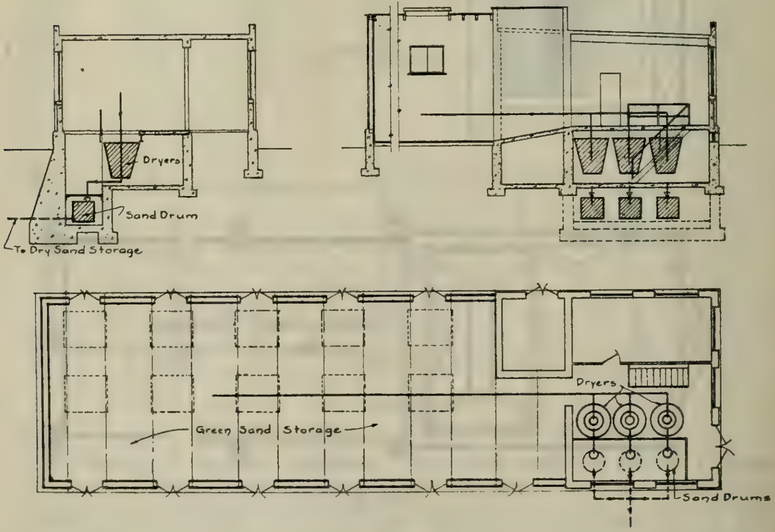
Dryers
Sand Drum
To Dry Sand Storage
Dryers
Green Sand Storage
Sand Drums

FIG. 4

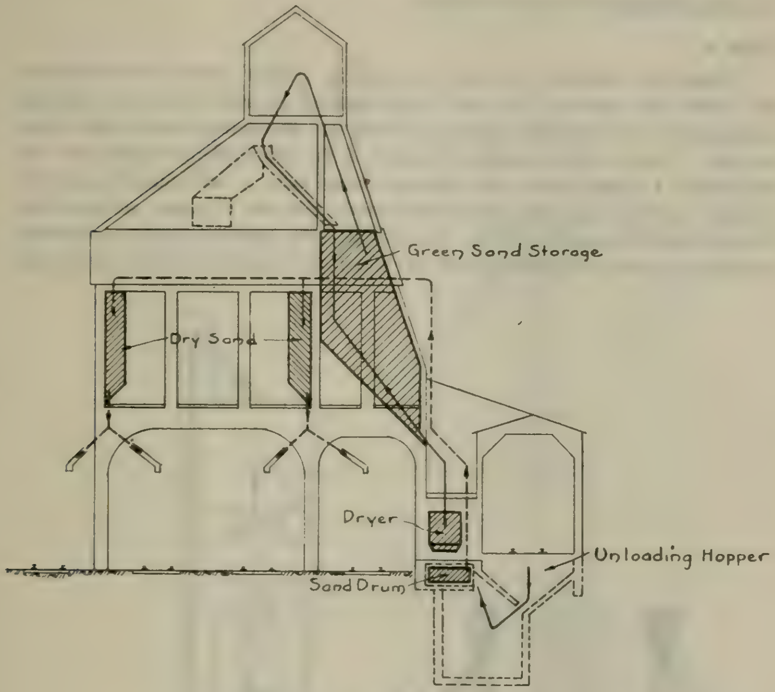
Green Sand Storage
Dry Sand
Dryer
Unloading Hopper
Sand Drum

FIG. 5

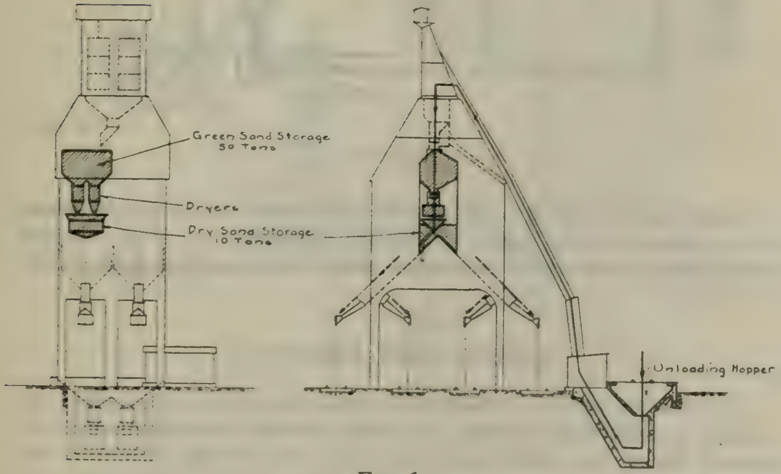
Green Sand Storage
50 Tons
Dryers
Dry Sand Storage
10 Tons
Unloading Hopper

FIG. 6

bin is used and the coaling station is a relatively high and compact structure. A typical example is shown in Fig. 6.

Type 4

Where the handling of coal in a coaling station cannot be interrupted and where the quantity of sand to be handled justifies it, or in locations independent from coaling stations, a complete mechanical sand plant may be used. Such a plant usually consists of an independent hopper for the unloading of green sand from bottom dump cars, a mechanical conveyor of some sort for elevating the green sand, and one or more storage bins of the required capacity. From the storage bins gravity operation through the driers to the sand drum can be arranged. Dry sand is elevated by means of compressed air to the dry sand storage compartment, which may be located in an adjacent coaling station or entirely independent of same. Typical arrangements for complete mechanical sand plants are illustrated in Fig. 7, 8, 9, 10.

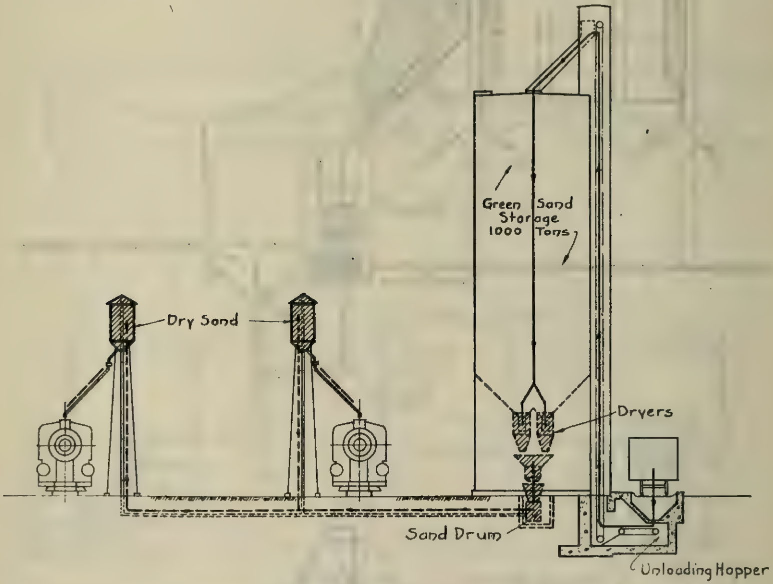

Fig. 7

GREEN SAND STORAGE

There seems to be no definite and uniform practice for determining the amount of green sand storage. In some localities deliveries cannot be secured during the winter and frequently even though deliveries can be secured sand freezes in cars before it can be unloaded. In such cases sufficient storage capacity to carry through the winter season should be provided. This usually means the provision of an inde-

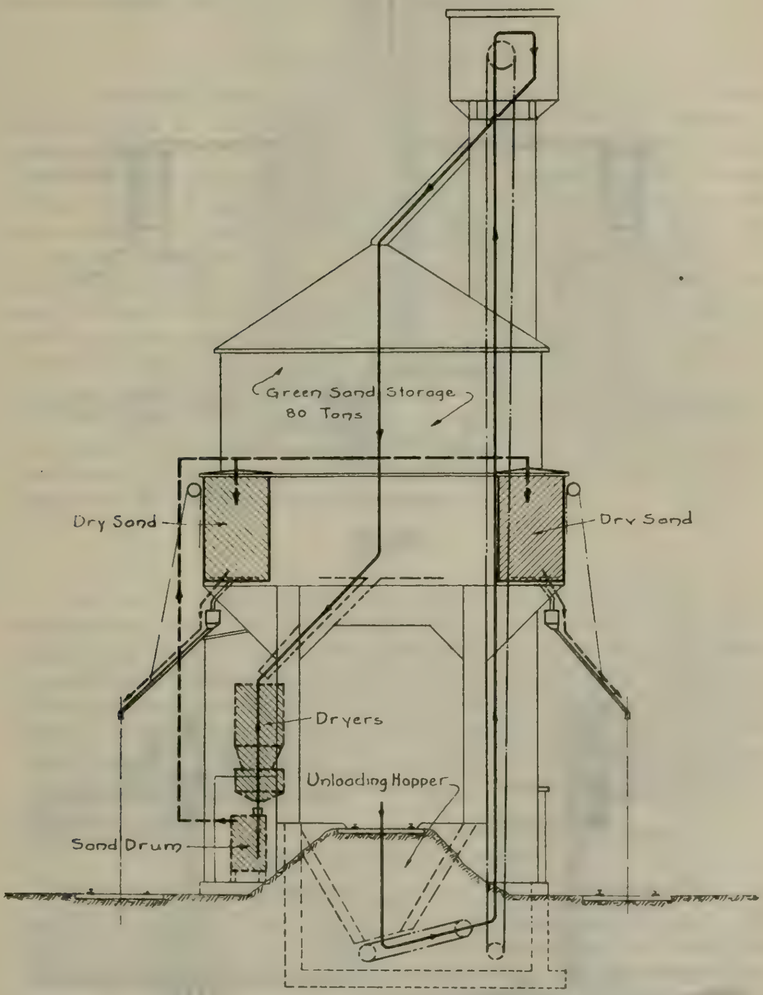
Green Sand Storage
80 Tons
Dry Sand
Dry Sand
Dryers
Unloading Hopper
Sand Drum

FIG. 8

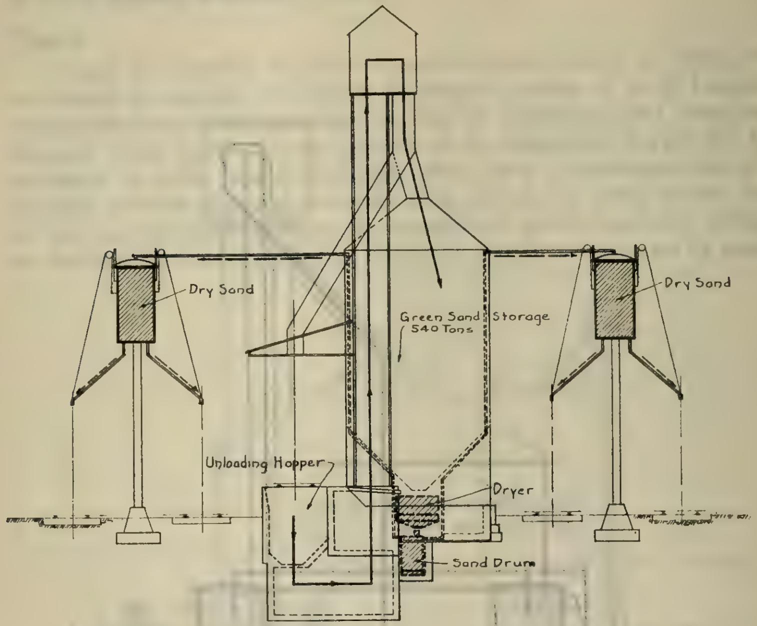
Dry Sand
Green Sand Storage
540 Tons
Dry Sand
Unloading Hopper
Dryer
Sand Drum

FIG. 9

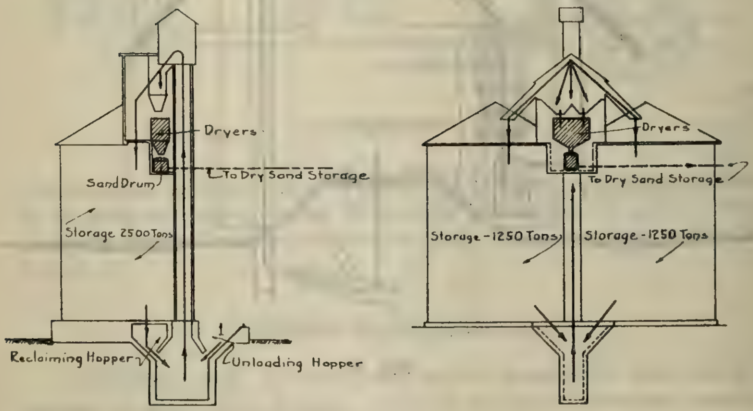
Dryers
Sand Drum
To Dry Sand Storage
Storage 2500 Tons
Reclaiming Hopper
Unloading Hopper
Dryers
To Dry Sand Storage
Storage - 1250 Tons
Storage - 1250 Tons

FIG. 10

pendent sand handling plant. Where green sand storage space is provided for in the coaling station structure the minimum space provided should be one car load or at least one week's supply if more than a car load. In an average coaling station of 400 to 600 tons coal storage capacity, it is usually not unduly expensive to provide also for the storage of 100 to 150 tons of green sand.

HANDLING GREEN SAND

As previously stated, it is the usual practice in Type 1 or ground storage plants to use laborers with wheelbarrows for the delivery of green sand to the driers. The cars are unloaded either by hand shoveling or with a clam shell bucket on locomotive or some other type of crane. Where Type 2 or Type 3 plants are used the coal elevating equipment can be used also for sand, where such equipment is of the skip hoist type, by placing temporary choke over loader opening and partially filling the bucket. Continuous bucket conveyors designed for coal cannot be used for sand without serious overloading on account of the difference in weight of the two materials and in such installations separate conveyor for sand handling is required. It will be noted from Fig. 10, which illustrates one of the independent sand plants, that a rather ingenious arrangement has been provided which while it requires the re-elevation of green sand to driers after same has been placed in storage, it has the advantage of economy of construction by placing bottom of storage bin on the ground and permits delivery of dry sand to tracks by gravity.

DRIERS

Sand can be dried successfully in either stove or steam driers. Where steam supply is available from central shop power plant it is usually considered good practice to use steam driers, as they can be operated without so much manual attendance and the fire hazard is also reduced. In any case, building or compartment housing driers should preferably be entirely of fireproof construction. Sufficient drier units should be provided to keep an adequate supply of dry sand on hand at all times. Examples of successful stove and steam sand driers are illustrated in Fig. 11, 12, 13, 14 and 15, respectively.

DRY SAND STORAGE

The capacity of dry sand storage bins varies considerably in actual practice, capacities ranging from 10 to 25 tons being generally used. The capacity selected for a given location should be sufficient to permit the establishment of a generous reserve for use during any unavoidable interruption in the operation of drier. When facilities are constructed in connection with a coaling station, dry sand storage compartment can readily be provided at some convenient location in that structure.

HANDLING DRY SAND

The generally accepted method of handling dry sand from drier to storage bin where gravity cannot be employed is by means of compressed

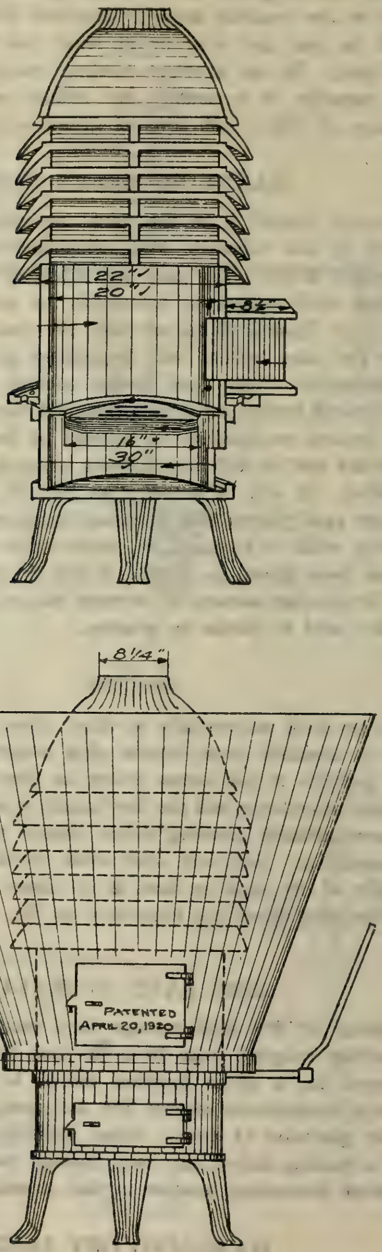

FIG. 11—SMALL STOVE SAND DRIERS

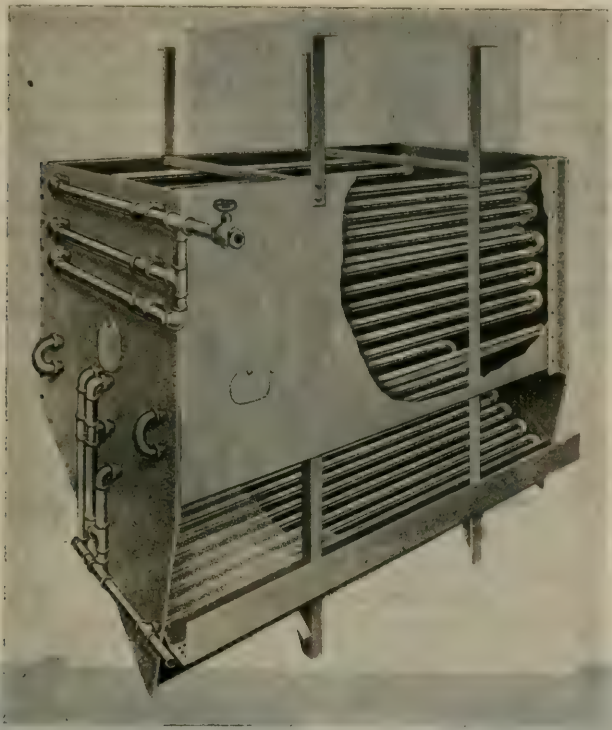

FIG. 12—STEAM SAND DRIER

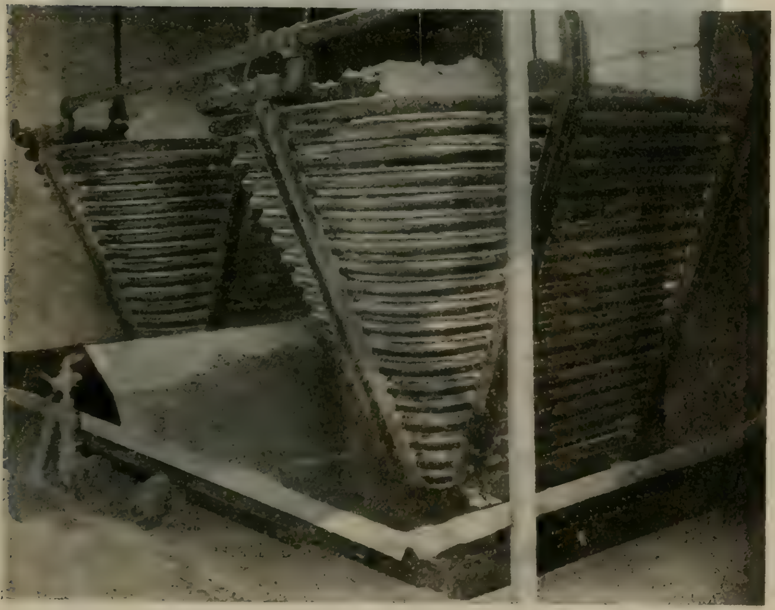

FIG. 13—STEAM SAND DRIER

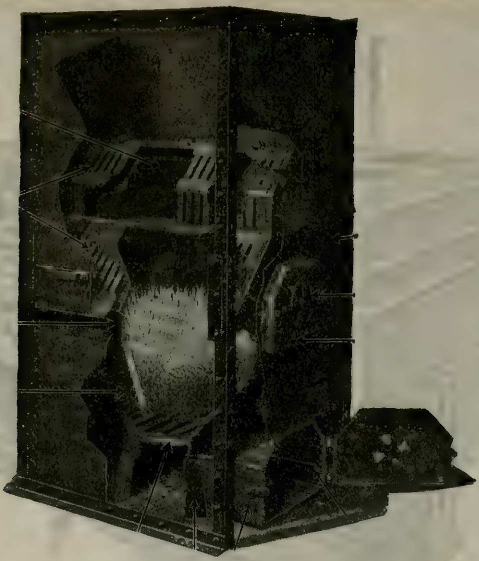

Fig. 14—Small Stove Sand Drier

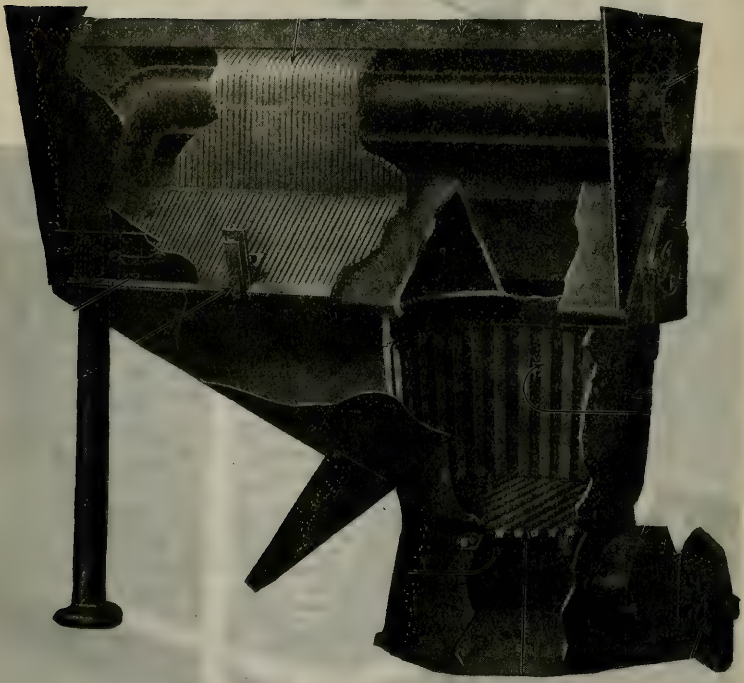

Fig. 15—Large Stove Sand Drier

air. In this method sand from drier is collected in batches of approximately one cubic yard in sand drum and air pressure is then applied. Usually 2½-inch pipe is used to convey sand from sand drum to storage bin. Such a pipe when properly installed can be used for the purpose without excessive wear. At points in pipe line where direction is changed it is good practice to use heavy tees with one tee opening plugged, thus forming a pocket which fills with sand for deflection purposes. Dry sand storage bin whether located in coaling station or independent of same should be placed at such an elevation that sand will readily flow by gravity to delivery fixtures. In cases where a large number of tracks are to be served it is sometimes necessary to provide two dry sand storage bins. Sand outlet fixtures for delivery to locomotives should be of the telescopic, counterbalanced type and equipped with weatherproof valves.

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